Intrapreneurship Infrastructure for Industrial Companies Pursuing New Ventures

A Thesis

Submitted to the Faculty

of

Drexel University

by

Carlo Stephen Ciliberti, Jr.

In partial fulfillment of the

requirements for the degree

of

Doctor of Philosophy

December 2015

Dedications

I dedicate my dissertation work to my family. First and foremost to my parents Janice and Carlo who have supported and encouraged me unconditionally throughout my life. They have instilled my desire to learn and to be the best that I can be through their love, inspiration and examples. The generations that have passed before me have all worked to make the lives of their children better which is what made this opportunity possible. To my wife, Dena, who watched me spend many long nights and weekends juggling school, work and daily activities. The many little acts of kindness like having gluten-free snacks ready and waiting and a big hug mean more to me than she will ever realize. To my daughter Tiffany whose excitement during her own pursuit of her college degree was inspirational and helped fuel my desires to forge ahead. And to my son, Carlo III, who not only stood by my side during two publication presentations working the power points at only 8 and 9 years old, but constantly reminded me through his actions that the true quest of learning starts with pure wonderment.

Acknowledgments

I wish to thank my committee members whose expertise, support, encouragement and time helped me achieve this life-long goal. Thank you Dr. Anthony Deese for your technical proficiency, guidance and assistance with Power and Electrical engineering as well as keeping me focused. Thank you Dr. Stephen Smith for your expertise, time and patience in business modelling, finance and economics. Thank you Dr. Robert Brehm for your guidance with engineering, procurement and construction issues as well as risk management. Thank you Dr. Sabrina Spatari for your skills and expertise in Life Cycle as well as your countless hours with publication assistance and direction.

I would also like to thank Dr. Sarah Jordaan for going out of her way to assist with environmental and energy policies as well as her dedication and skills developing manuscripts for publication. Dr. Jordaan's enthusiasm and zest for achievement are infectious as well as inspiring.

A very special thank you to Dr. Joseph Martin, my committee chairman, who not only took me under his wing but also provided his encouragement and friendship every step of the way. Dr. Martin's mentoring, stories and acts of kindness give true meaning to the word "teacher". He always left me with renewed dedication and desire to continue throughout the entire process.

In addition to my committee members, I would also like to thank Kristen Johnson, Chris Morse, and Jessica Atchison who have greatly contributed to my continuing education and dedication to Drexel University. They're professionalism, constant support, positive demeanors and unique abilities to achieve results are remarkable. They are the true foundation to a great institution.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Intrapreneurship Infrastructure for Industrial Companies Pursuing New Ventures

Carlo Stephen Ciliberti, Jr.

Joseph P. Martin, PhD

Corporations that foresee diminishing markets for their traditional goods and services must find new products or markets to stay competitive. Technology based industrial firms with production assets usually foster a culture of continuous new product improvement and development, but this will not solve the problem of a diminishing market, e.g. Defense. Future prosperity of the entity may depend upon either entering or creating new markets. The goal is to develop new systems that leverage assets, corporate culture, and also, address the prevailing public context.

Key corporate assets are mid-level engineers who have both technical and management savvy, and also, understand the relationship between career and corporate success. They are the ideal candidates to form groups of intrapreneurs to use the resources of their corporate entity to develop and implement innovative concepts. This is often done for new products anyway, but to enter new markets with a particular competitive context, or to develop systems to serve emerging markets, a fresh, lean, new venture subdivision might be required. This dissertation describes a new process for industrial corporate engineers taking a concept, and determining if it is viable to propose to senior leadership to form a new intrapreneural venture within the corporation. Proposals involving consideration of technical, managerial, social and political elements leveraging long-term system operation solutions are emphasized. Since competitors realize similar opportunities, understanding the advantages and shortfalls of corporate culture is critical.

The focus in this dissertation is renewable energy and the unique way to produce, manage and deliver products that are already in demand as either fuel or power. The context is public support and decision making that considers many factors beyond traditional cost vs. revenue benefit for the provider and direct user only. Positive and negative external impacts influence decisions and impact economic analysis through subsidies and guaranteed market share. There are three critical engineering issues with meteorologically based renewable power: mis-match between supply and demand; dispersed generation; and distance to urban

markets. However, in agricultural areas with abundant natural resources, the concerns with these critical engineering issues are mitigated, even if they are distributed at low intensity. Moreover, such areas have byproducts that may be used as feedstock to produce fuels that can compensate for the troughs in power production, be used directly, or both.

An integrated system of matching renewable power to agricultural demand is geographically based. The example used here is the Northern High Plains, a rich source of wind power. A flyover reveals that thousands of acres in the Dakotas is used for dairy and oilseeds, both with high local energy demand and production of organic byproducts. Power is now supplied by locally based Rural Electrical Associations (REAs), which only distribute the power produced primarily by coal-fired power plants using the Missouri and Red Rivers for evaporative cooling. In the current context, this presents the opportunity for an integrated system to provide REAs with power from local sources, and also produce biogas fuel for power production and local heating. Furthermore, it may be possible to use excess renewable power to process biogas or seed oil for sale as motor fuel, or export as gas. A significant feature of such an integrated system is long-term operation and system integration. Hence, industrial firms may have an institutional advantage in competition with traditional infrastructure EPC (Engineering-Procurement-Construction) firms.

The process and steps taken by a cadre of engineers in an industrial corporation to develop an intrapreneural proposal from a basic idea is described in this dissertation using the integrated rural renewables facility and operating entity as an example. Not only are technical, organizational, managerial and financial issues intertwined, but an immense amount of research in unfamiliar fields (agriculture, climate, etc.) is required to develop a unique and technically competitive offering.

CHAPTER 1: INTRODUCTION

In a comprehensive study of more than six million U.S. firms, Stubbart and Knight noted that only a tiny fraction of firms live to age 40. For example, for firms founded in 1976, only 10% survived 10 years later, leading them to conclude that “Despite their size, their vast financial and human resources, average large firms do not ‘live’ as long as ordinary Americans” (O’Reilly et. al, 2009). Another statistic shows that one-third of the firms in the Fortune 500 in 1970 no longer existed in 1983. Studies of organizational mortality have revealed that large firms have an estimated residual life expectancy from 5.8 to 14.6 years. Given large firms experience, financial capabilities, core competencies, strategic assets, etc. – why aren’t large firms more successful? And what have the firms that do survive, do differently from the norm? (O’Reilly et. al, 2009). The difference points to Intrapreneurship and the ability to explore and capitalize on new ventures that are strategically aligned with the company’s core competencies.

Corporations experiencing diminishing traditional markets must reposition themselves to develop new markets to stay competitive. Forward-thinking corporations rely on internal entrepreneurial efforts to alter an organization's status quo, harness the energies of talented renegades, and give sponsorship to promising businesses that are unrelated to the company's cash cow (Tarkahashi, 2000). Many mid-level engineers within such companies are both technically and management savvy, and also understand the relationship between career and corporate success. They are ideal candidates to form groups of intrapreneurs to develop and implement innovative concepts using the corporate resources of a large industrial entity in a fresh, lean new venture subdivision. "Look back at any great business or invention at just about any big company and you can find that intrapreneurs created it," says Gifford Pinchot, author of *Intrapreneuring*. Mr. Pinchot finds that 30 percent of large companies now provide seed funds that finance in-house entrepreneurial efforts (Pinchot, 1985).

However, studies such as by Duncan et. al. (2001) describe corporate problems trying to encourage and nurture intrapreneurship since few organizations are genuinely committed to attracting, hiring, and developing the creative talent they will need in the future. Creative people, while possessing the traits and characteristics ideal for intrapreneurship, also exhibit traits conducive to disrupting established corporate order by experimenting with new ways of doing things. Corporate strategy based on principles of responsibility relating to ability and reward related to service can have a positive influence on intrapreneurship as practiced more than 50 years ago by Henry Dennison at Dennison Manufacturing (Duncan, 2001). Even though intrapreneurs may desire autonomy and financial freedom more than monetary rewards, they will not be satisfied to generate ideas that give others profit without an equitable share of the payoff. To believe that intrapreneurs do not need money is to guarantee that that people with ideas will do their creating in their garages, for a competitor, or both. Another corporate determent to intrapreneurship is that the focus on short term results and the prevailing view of the professional manager as an agent of owners, ensure that people who begin as intrapreneurs will find it necessary to become entrepreneurs if their ideas are to provide any personal benefits other than steady employment (Duncan, 2001).

This dissertation describes a process that can be used as a guide for intrapreneurs and corporations who take an idea from conception to corporate senior leadership for approval such that a new venture can be established within the corporation. The intrapreneural process, which is the objective of the research, was developed through intrapreneurship exploration including investigations on failed intrapreneural new ventures; and examinations on successful intrapreneural new ventures. The process will be described through the development of an idea of establishing an integrated system to supply rural electric cooperatives with power and fuel using renewable resources from an engineer inside a large industrial corporation as a response to the opportunity presented by the public for support of sustainable and renewable energy initiatives will be investigated. Specifically, the High Plains of the United States which are a rich source of wind power and biomass feedstock, but are distant from urban markets, and distributed at low intensity will be analyzed to determine the feasibility of a new venture to use local sources to satisfy rural residential and industrial / agricultural power demand and also to process fuels for local and export sales. Excess wind power can be converted to and stored as marketable biofuels when peak load is less than peak energy output. The process and steps taken by the engineers and the corporation to analyze and develop this idea into a viable new venture opportunity will be presented thru this example.

CHAPTER 2: INTRAPRENEURSHIP – LEARNING FROM PAST SUCCESSES

IBM is one such company that has survived, even after the company went from being hugely successful to the brink of bankruptcy after 75 years being in business. IBM was able to return to success and profitability by realigning itself and incorporating intrapreneurship to explore and capitalize on new ventures that are strategically aligned with the company's core competencies.

2.1 History of IBM

In 1900, the International Time Recording Company (ITR) was created by George Fairchild by combining the Bundy Manufacturing Company, Willard & Fricke Manufacturing Group and Standard Time Stamp Company (Antique Clocks Guy, 2015). The Bundy Manufacturing Company was incorporated in 1889 by Willard L. Bundy who invented the time recording clock in 1888 (IBM, 2015). Willard & Fricke Manufacturing Group was formed in 1894 by J. L. Willard and F. A. Frick of Rochester, New York. They developed the first card time recorder. The Standard Time Stamp Company also manufactured time stamps and a card reader (IBM, 2015). All of these three companies had commonality with respect to recording time clocks, the kind factory workers would punch on the way in and out of work. The clocks helped employers keep track of hours worked and wages (IBM, 2015).

On June 16, 1911, the Computing-Tabulating-Recording Company (CTR) was created by the merger of The International Time Recording Company, Computing Scale Company, and the Tabulating Machine Company. Based in New York City, the company had 1,300 employees and offices and plants in Endicott and Binghamton, New York, Dayton, Ohio, Detroit, Michigan, Washington, D.C., and Toronto, Ontario (1BM, 2015). The companies' combined revenue for fiscal year 1910 was "excess of $950,000" (Madrigal, 2011).

Prior to the formation of CTR, Herman Hollerith, who formed the Tabulating Machine Company, won a contest sponsored by the U.S. Census Bureau to find a more efficient means of tabulating census data after recognizing that the traditional counting methods were inadequate. Traditional counting methods were deemed inadequate as a result of the influx of new immigrants entering the United States during the height of the Industrial Revolution. Hollerith was a Census Bureau statistician and invented the Punch Card Tabulating Machine which used an electric current to sense holes in punched cards and keep a running total of data. Not only could the machines count faster, but they could understand information in new ways. For record keeping, a single card, about three inches by seven inches, could be punched with holes that formed an information portrait of a person, complete with data such as city of residence, age, nationality, job and more. The millions of cards were able to be sorted and counted to determine such statistics as how many teachers lived in Chicago, Illinois, or count any other subset of the population. Society could now learn new statistical information as never before, and at speeds no one thought possible (IBM, 2015).

In 1914 Thomas J. Watson, Sr., was named general manager of CTR. Watson implemented a series of effective business tactics: generous sales incentives, a focus on customer service, an insistence on well-groomed, dark-suited salesmen and an evangelical fervor for instilling company pride and loyalty in every worker. Watson boosted company spirit with employee sports teams, family outings and a company band. He preached a positive outlook, and his favorite slogan, "THINK," became a mantra for C-T-R's employees. Within 11 months of joining C-T-R, Watson became its president. The company focused on providing large-scale, custom-built tabulating solutions for businesses, leaving the market for small office products to others. During Watson's first four years, revenues more than doubled to $9 million. He also expanded the company's operations to Europe, South America, Asia and Australia (IBM, 2015).

Watson emphasized research and engineering and remained at the helm for the next twenty years, turning the company into a multi-national entity foreseeing that information technology had an ever-expanding future and literally created the information industry (Bellis, 2015).

In 1924, Watson changed the company’s name to International Business Machines Corporation or IBM. From the beginning, IBM defined itself not by selling products, which ranged from commercial scales to punch card tabulators, but by its research and development. IBM was also known as "Big Blue" after the color of its logo (Bellis, 2015).

IBM began designing and manufacturing calculators in the 1930s, using the technology of their own punch card processing equipment (Bellis, 2015). In 1935, the United States adopted Social Security and IBM's punched card machines helped with the massive record keeping required for tens of millions of Americans. Businesses quickly realized that the portraits on those cards didn’t have to be citizens, but could be company product, freight car on a rail line, or an insurance customer. Early adopters of the electric tabulation method included the Eastman Kodak Company, which used a tabulating machine to keep track of customers and salesmen (Madrigal, 2011).

During the Great Depression of the 1930s, IBM managed to grow while the rest of the U.S. economy floundered. During these perilous times, Thomas J. Watson, Sr. took care of his employees. The IBM Schoolhouse was completed at Endicott, NY in 1933 to provide education and training for employees. IBM was among the first corporations to provide group life insurance (1934), survivor benefits (1935) and paid vacations (1937). While most businesses had shut down, Watson kept his workers busy producing new machines even while demand was slack. Thanks to the resulting large inventory of equipment, IBM was ready when the Social Security Act of 1935 brought the company a landmark government contract to maintain employment records for 26 million people. It was called "the biggest accounting operation of all time," and it went so well that orders from other U.S. government departments quickly followed.

When World War II began, all IBM facilities were placed at the disposal of the U.S. government. IBM's product line expanded to include more than three dozen major ordnance items including bombsights, rifles and engines. IBM also helped keep track of vital statistics such as U.S. freight traffic. In addition, Thomas Watson, Sr. set a nominal one percent profit on these ordnance products and used the profit money to establish a fund for IBM widows and orphans resulting from war casualties (IBM, 2015). In 1944, IBM co-developed its first computer, the Automated Sequence Controlled Calculator (aka Mark I), with Harvard University which was used by the U.S. Navy to calculate gun trajectories (Madrigal, 2011). It was the first machine that could execute long computations automatically. The Mark 1 was over 50 feet long, eight feet high and weighing almost five tons. It took less than a second to solve an addition problem but about six seconds for multiplication and twice as long for division (IBM, 2015).

The 1950’s were marked by IBM’s own reckoning, “The Golden Age of IBM”. In 1952, Thomas J. Watson, Jr., became the president of the company (Madrigal, 2011) and IBM introduced the IBM 701, its first large computer based on the vacuum tube. The tubes were quicker, smaller and more easily replaced than the electromechanical switches in the Mark I. The 701 executed 17,000 instructions per second and was used primarily for government and research work. Vacuum tubes rapidly moved computers into business applications such as billing, payroll and inventory control (IBM, 2015). By 1959, transistors were replacing vacuum tubes. The IBM 7090, one of the first fully transistorized mainframes, could perform 229,000 calculations per second. The U.S. Air Force used the 7090 to run its Ballistic Missile Early Warning System. IBM led data processing in a new direction with the 1957 delivery of the IBM 305 Random Access Method of Accounting and Control (RAMAC), the first computer disk storage system. Such machines became the industry's basic storage medium for transaction processing. In less than a second, the RAMAC's "random access" arm could retrieve data stored on any of the 50 spinning disks. Also in 1957, IBM introduced FORTRAN (FORmula TRANSlation), a computer language based on algebra, grammar and syntax rules. It became one of the most widely used computer languages for technical work (IBM, 2015).

Just as his father saw the company's future in tabulators rather than scales and clocks, Thomas J. Watson, Jr., foresaw the role computers would play in business, and he led IBM's transformation from a medium-sized maker of tabulating equipment and typewriters into a computer industry leader (IBM, 2015).

The 1960’s began with IBM employees passing 100,000 people. During this period, IBM made and sold massive computers to large governments and corporations. IBM's computers helped businesses both manage and produce massive amounts of data, thereby assuring that ever more powerful machines would be needed to keep up with both sides of the information problem (Madrigal, 2011). On April 7, 1964, IBM introduced the System/360, the first large "family" of computers to use interchangeable software and peripheral equipment. It was a bold departure from the monolithic, one-size-fits-all mainframe. The System/360 offered a choice of five processors and 19 combinations of power, speed and memory. A user could operate the same magnetic tape and disk products as another user with a processor 100 times more powerful. The System/360 also offered dramatic performance gains, thanks to Solid Logic Technology - half-inch ceramic modules containing circuitry far denser, faster and more reliable than earlier transistors.

In 1969, IBM changed the way it sold technology. Rather than offer hardware, services and software exclusively in packages, marketers "unbundled" the components and offered them for sale individually. Unbundling gave birth to the multibillion-dollar software and services industries (IBM, 2015).

In the 1970’s, the computer industry expanded and wove its way into everyday life. IBM introduced the floppy disk in 1971, and quickly became the standard for storing personal computer data. When people shopped for groceries, IBM's supermarket checkout station, introduced in 1973, used glass prisms, lenses and a laser to read product prices. Also in 1973, bank customers began making withdrawals, transfers and other account inquiries via the IBM 3614 Consumer Transaction Facility, an early form of today's Automatic Teller Machines (IBM, 2015).

The appointment of John R. Opel as CEO in 1981 coincided with the beginning of a new era in computing. Thanks to the birth of the IBM Personal Computer or PC, the IBM brand began to enter homes, small business and schools. Though not a spectacular machine by technological standards, the IBM PC brought together all of the most desirable features of a computer into one small machine. It offered 16 kilobytes of user memory (expandable to 256 kilobytes), one or two floppy disks and an optional color monitor. When designing the PC, IBM for the first time contracted the production of its components to outside companies. The processor chip came from Intel (IBM, 2015). It was in July 1980, that Microsoft's Bill Gates agreed to create an operating system called DOS (Disk Operating System) for IBM's new computer for the home consumer. IBM had now stepped into the home consumer market, sparking the computer revolution (Madrigal, 2011).

John F. Akers became CEO in 1985 and focused on streamlining operations and redeploying resources. During Akers' tenure, IBM's significant investment in research achieved breakthroughs in mathematics, memory storage and telecommunications, and made great strides in expanding computing capabilities. The IBM token-ring local area network, introduced in 1985, permitted personal computer users to exchange information and share printers and files within a building or complex. With the further development of the computer, IBM laid a foundation for network computing and numerous other applications (IBM, 2015).

2.2 IBM’s Downward Slide

During the late 1980s and early 1990s, IBM was thrown into turmoil by back-to-back revolutions. The PC revolution placed computers directly in the hands of millions of people. And then, the client/server revolution sought to link all of those PCs (the "clients") with larger computers that labored in the background (the "servers" that served data and applications to client machines).

Both revolutions transformed the way customers viewed, used and bought technology. And both fundamentally rocked IBM. Businesses' purchasing decisions were put in the hands of individuals and departments - not the places where IBM had long-standing customer relationships. Piece-part technologies took precedence over integrated solutions. The focus was on the desktop and personal productivity, not on business applications across the enterprise (IBM, 2015).

IBM went from employing over 400,000 employees in 1986 to slightly more than 200,000 employees in 1994. Prior to this point, IBM had avoided layoffs for more than 70 years. This was in direct contradiction to IBM's philosophy of promoting lifetime employment and IBM's stock price fell to the lowest it had been since 1983 (Harreld et. al., 2006).

In 1990, IBM sales were five times their nearest rival, but growth had slowed to less than six percent. By 1993, the company's annual net losses reached a record $8 billion. Cost management and streamlining became a chief concern (IBM, 2015). And IBM seriously considered splitting its divisions into separate independent businesses as the company executives started to comprehend how drastically IBM was sinking.

The existing culture at IBM failed to accurately sense changes in their competitive environment and failed to act on opportunities and threats. The culture and hierarchy at IBM from senior management on up, interfered with IBM's ability to grow and survive. IBM's cultural impediments coupled with dated core competencies became less valuable as competitors replicated them and the markets shifted. IBM became unable to reconfigure its assets and competencies to address changing market circumstances. Even John Akers claimed that "Everyone is too comfortable at a time when the business is in crisis". Other analysts at the time described IBM's position as a "dangerous mix of arrogance and complacency" (Harreld et. al., 2006).

On January 26, 1993, in the face of looming disaster, CEO John Akers resigned. In addition, many of Akers' direct reports also announced their departures from IBM soon after he resigned (Harreld et. al., 2006).

2.3 Enter Louis Gerstner

On April 1, 1993, Louis V. Gerstner, Jr. became the first IBM CEO from "outside" the company. Prior to joining IBM, Gerstner had been chairman and CEO of RJR Nabisco for four years; a top executive at American Express for eleven years; and a successful management consultant at McKinsey & Co. (IBM, 2015).

After several months on the job, Gerstner's diagnosis of the company's problem was clear: Costs were out of line, they had lost touch with customers, the firm was too decentralized, and they had stayed with their old strategy too long. He stated, "We don't move fast enough in this company. This is an industry in which success goes to the swift more than the smart. We've got to become more nimble, entrepreneurial, focused, cost driven….we've been too bureaucratic and preoccupied with our own view of the world…" (Harreld et. al., 2006). Gerstner knew that the company didn't lack for smart, talented people. They had file drawers full of winning strategies. Yet, the company was frozen in place. It needed a strategic and cultural change, a focus on "can-do" attitudes regarding solutions and actions (Gerstner, 2002).

Gerstner recognized that the market was shifting beyond IBM's core competencies. The application of technology, not its invention, would become the growth engine for IBM. This was a completely different approach than the old IBM business model. In analyzing why IBM found itself failing, he noted that "What happened to this company was not an act of God, some mysterious biblical plague sent down from on high. It's simple. People took our business away." Gerstner's insights led to a transformation that subsequently led IBM to exit the network hardware business, application software, storage and personal computers and to enter the services businesses and develop a freestanding software business (Harreld et. al., 2006).

After stabilizing the company in the mid-1990s, Gerstner described IBM's bet on the future this way: "Our bet was this: Over the next decade, customers would increasingly value companies that could provide solutions – solutions that integrated technology from various suppliers and, more importantly, integrated technology into the process of the enterprise…In services, you don't make a product and sell it. You sell a capability…this is the kind of capability you cannot acquire." (Harreld et. al., 2006).

In September of 1999, Gerstner was reading a monthly report that indicated that current financial pressures had forced a business unit to discontinue funding of a promising new initiative. Gerstner was incensed and demanded to know "Why do we consistently miss the emergence of new industries?" Underscoring this question were the results of a study by the IBM strategy group documenting how the company had failed to capture value from 29 separate technologies and businesses that the company had developed but failed to commercialize. For example, IBM developed the first commercial router but Cisco dominated the market. As early as 1996, IBM had developed technologies to accelerate the performance of the web, but Akamai, a second-mover, had the product vision to capture the market. In another example, IBM developed speech recognition software but their initiative was eclipsed by Nuance. In each instance, the conclusion was that IBM had the potential to win these markets but had failed to take advantage of the opportunity. The question was "why" this happened (O'Reilly et. al., 2009).

A detailed internal analysis of why the company missed these markets revealed six major reasons IBM routinely missed new technology and market opportunities. These included:

1) A management system that rewarded execution directed at short-term results and did not value strategic business building. The dominant leadership style rewarded within the company was to execute flawlessly, not to pioneer into new area.
2) The company preoccupation with current served markets and existing offerings. This made IBM slow to recognize disruptive technologies and to recognize new markets.
3) A business model that emphasized sustained profit rather than actions oriented towards higher price/earnings. The emphasis was geared toward improving profitability of a stable portfolio rather than accelerating innovation. The unrealistic expectation was that new businesses needed to break even within a year or two.
4) An inadequate approach to gathering and using market insight for embryonic markets. The insistence on "fact-based financial analysis" hindered IBM's ability to generate market intelligence for new and ambiguous markets.
5) Lack of discipline for selecting, experimenting, funding, and terminating new growth businesses. Even when new growth business opportunities were identified, IBM's existing management systems failed to provide funding or restrict its ability to develop creative new businesses. Worse, the company applied its mature business process to growth opportunities with the result that it often starved these new ventures.
6) Lack of entrepreneurial leadership skills for designing new business models and building growth businesses. It also lacked the patience and persistence that new start-ups require (O'Reilly et. al., 2009).

The first three root causes were contradictory to much of IBM's success in mature markets – the intense focus on short-term results, careful attention to major customers and markets, and an emphasis on improving profitability. These all contributed to the firm's ability to exploit mature markets – and made it difficult to explore new spaces.

As a result of this analysis and the discussions it generated among senior management, a series of recommendations were made to permit the company to succeed at both exploitation in mature markets and exploration in growth areas. These decisions resulted in the development of the Emerging Business Organization initiative in 2000 (O'Reilly et. al., 2009).

2.4 Emerging Business Opportunities

The Emerging Business Opportunities (EBOs) team was formed to explicitly address IBM's chronic failure to rapidly and successfully pursue new market opportunities. A foundational insight of the team was the recognition that the company's portfolio of businesses could be divided into three horizons: current core businesses; growth businesses; and future growth businesses – with each type of business having unique challenges and requiring a different organizational architecture (O'Reilly et. al., 2009).

Emerging Business Opportunities (EBOs) developed an integrated set of processes, incentives and structures designed explicitly to enable IBM to address new business opportunities. An EBO focuses on "white space" opportunities that can become profitable, billion-dollar businesses within five to seven years (Wong, 2008). The EBO process begins with the recognition that mature, well-established businesses need to operate differently from new, exploratory ones. To succeed, emerging businesses have different key success factors and require a different style of leadership and different alignments of people, formal organizations and culture. IBM recognized that the current management system that rewarded short-term execution aimed at current markets did not apply to EBOs. Trying to operate new business with the same business model typically results with the new business being terminated. Further, the company lacked the discipline for selecting, experimenting, funding and terminating new businesses for the proper reasons. This led to the development of a process to identify new growth opportunities and to establish separate organizations with their own leadership, alignment, and funding – all with senior management oversight to ensure that the new businesses got the resources needed to explore the opportunity. Under the new system, it was made crystal clear that EBOs are not product upgrades or just technical opportunities; they're business opportunities – ones that can be commercialized and turned into revenue-producing businesses (Harreld et. al., 2006).

IBM's EBO program can be viewed as a group of startup companies being developed and nurtured inside the management constructs of the industry's largest information technology company (Nunes, 2004). The EBO program is intrapreneurship and the IBM intrapreneurship model is adapted from The Alchemy of Growth (Baghai,et. al. 2000). The model distinguishes new ventures from established businesses on three levels defined as Horizon 1 (H1), Horizon 2 (H2), and Horizon 3 (H3) businesses. H1 businesses are mature and managed with a focus on current revenue and profit. The H1 businesses are the "cash cows" which return the bulk of profits and cash flows (Wilkens, 2005). H2 businesses have a longer time frame and are more uncertain. Milestones are based on revenue growth and market share gains.

The EBO process begins when growth opportunities are identified that require significant cross-organization integration to be successful (Harreld et. al., 2006). Gerstner announced the appointment of John Thompson, then head of the software group, as Vice Chairman and head of the new EBO initiative. Thompson was a 34-year veteran of the company and was widely respected for his skills as an operating manager and strategist.(O'Reilly et. al., 2009). Thompson developed and EBO management and funding process for cross-company alignment. Each emerging business opportunity had to meet the following criteria:

- Strategic Alignment with the IBM corporate strategy
- Cross-IBM Leverage – focus on generating new businesses that cut across the IBM organization.
- New Source of Customer Value – ideas that allow the company to move into new domains and test new business models are preferred over better understood models
- $1 Billion Plus Revenue Potential – Potential of growing into a billion dollar market within three to five years.
- Market Leadership – New business ideas must also provide the opportunity for IBM to emerge as the market leader.
- Sustained Profit – Have a good chance for the business to sustain profitability (O'Reilly et. al., 2009).

To identify new emerging business opportunities, IBM developed a semi-annual process in which ideas are solicited from both within the company and outside the company. This effort typically results in more than 150 ideas. These ideas are reviewed and down-selected to the top 20 or so then small teams are formed to perform more detailed strategic analysis. After the analysis, the ideas are socialized among senior executives and customers to determine acceptance. If an idea is deemed to have merit, the strategy group then performs a “deep dive” to properly vet the market opportunity with the goal of building new billion dollar businesses. Establishing a new EBO links new business venture ideas to real customer benefits. Of the 150 ideas generated each year, only a few are chosen as new EBOs (O’Reilly et. al., 2009).

Once an EBO is formed, the corporate strategy group acts as the agent and partner for the EBO. They meet monthly to review progress, refine strategy, and help them get the right people and alignment to ensure execution. The key principles established for the success of an EBO are:

- Active and Frequent Senior-Level Sponsorship – lack of senior management attention to new ventures was a lessons learned in the strategy group of IBM’s failures to enter new businesses in the past.
- Dedicated “A-Team” Leadership – Very experienced leaders are assigned since historically IBM’s younger managers often lacked the networks needed to nurture and embryonic business within the larger company
- Disciplined Mechanisms for Cross-Company Alignment – Ensure that the line businesses provide the requisite support, even when it may run counter to their short-term interests.
- Resources Fenced – and Monitored – to Avoid Premature Cuts – EBOs are funded through their line of business, but the process is carefully monitored to make sure that the new business receives its full funding.
- Actions Linked to Critical Milestones – Carefully define and monitor progress in meeting milestones. Businesses are measured against these milestones and not the financial merits of their line of business. This protects embryonic ventures from being terminated too early for a failure to achieve mature business targets.

- Quick Start, Quick Stop – If the new business doesn't meet its milestones and connect with customers, it needs to be stopped or morphed into something else. The intent is to get into the market quickly, learn from it, and adjust accordingly or stop the effort (O'Reilly et. al., 2009).

From 1999 to 2005, 18 opportunities were identified, including autonomic computing, blade servers, digital media and network processing. Some of these succeeded and were subsequently folded into existing businesses while others failed (Harreld et. al., 2006). Between 2000 and 2005, EBOs added $15.2B to IBM's top line. While acquisitions over this period added 9 percent to IBM's top line, EBOs added 19 percent. This process has enabled the company to explore and exploit – to both enter new businesses and to remain competitive in mature ones (O'Reilly et. al., 2009).

2.5 IBM's Emerging Business Opportunities Success

In 2000, an EBO for a new Life Sciences business started since market studies suggested that there were significant scientific and market opportunities in applying high-performance computing and information technology to the emerging areas of biotechnology and personalized medicine even though and earlier IBM effort had recently failed. The opportunity as to help customers in academia, government, pharmaceuticals, and hospitals integrate the massive amounts of information being generated. To succeed, IBM would have to help these customers develop integrated solutions, not sell existing products. This required both though leadership and integration across four major IBM silos (O'Reilly et. al., 2009).

Between April 2000 and November 2006, the Life Sciences business grew to a $5 billion business with hundreds of PhDs in life sciences (O'Reilly et. al., 2009).

Although the market opportunity in Life Sciences was recognized in 1998, several early attempts to enter this market failed. Funding from the lines of business wasn't forthcoming, there was a lack of entrepreneurial leadership, and the IBM processes and metrics that helped mature businesses actively worked against the establishment of the new venture. It was only with the development of the EBO process that these barriers were removed. The combination of a clear strategic intent, guaranteed funding, senior-level sponsorship, entrepreneurial leaders, and an aligned organization were required for the venture to succeed (O'Reilly et. al., 2009).

Without the senior-level support and typical internal oppositions encountered, many entrepreneurial leaders may quit and take their ideas elsewhere. The same issues have led some firms to isolate their new ventures. However, upon reflection, this approach fails to leverage the capabilities and resources of the larger company. It ignores the critical issues of integration, sharing and leveraging of resources and fails to infuse entrepreneurial leadership into the larger company (O'Reilly et. al., 2009).

2.6 Lessons Learned IBM's EBO Successes

Louis Gerstner stated that early on in his career he discovered, to his dismay that the open exchange of ideas in that absence of hierarchy doesn't work so easily in a large, hierarchical-based organization. He began a lifelong process of trying to build organizations that allow for hierarchy but at the same time bring people together for problem solving, regardless of where they are positioned within the organization (Gerstner, 2002).

When Gerstner entered IBM, he was not technical by any means. He knew that he would have to learn IBM's technology but he made no attempts to master it. He relied on his unit leaders to be the translators into business terms that he understood and excelled at. Gerstner also is not a fan of hierarchy. His solutions were to find the problem solvers, regardless of position and reduce committees and meetings. He removed committee decision making and encouraged candid communications. After joining IBM, Gerstner quickly surmised that most, if not all, of the business processes were expensive and inefficient. Therefore change was needed. Michael Hammer, coauthor of "Reengineering the Corporation" told the New York Times" "Gerstner decided that sooner is better than perfect – that was the anathema to the old OBM. This is the most important kind of change that can come from the top." (Gerstner, 2002).

Gerstner acknowledged that it would have been "absolutely naïve – as well as dangerous" if he had come into a company as complex as IBM with a plan to import a "band of outsiders" to somehow magically run the company better than the people who were there in the first place and had talent and unique expertise (Gerstner, 2002).

Gerstner also knew from past experiences that intense rivalries between units of a large company were a prevalent behavior pattern. The units that had been the traditional base of a company more often than not resisted the emergence of a new sibling, even homegrown (Gerstner, 2002).

EBO successes were due in part to IBM's culture. Gerstner stated that, "I came to see, in my time at IBM, that culture isn't just one aspect of the game – it is the game." In the end, an organization is nothing more than the collective capacity of its people to create value.

2.7 Comparison to Other Recent Successes

Similar to IBM, Nokia and Shell have thriving corporate ventures for developing new business within their large established firms (Shah et. al, 2008).

Shell, an integrated oil and gas company, is involved with venturing through its GameChanger (GC) program. GC was started in 1996 with a team of twelve dedicated technical and scientific experts that have the potential to drastically impact the future of energy. This program combines the support from Shell with "the freedom to make their own decisions". One such idea that flourished into massive returns in from Barend Pek, a Dutch engineer and expert at turning natural gas, the cleanest-burning fossil fuel, into liquid. Advanced technology cools the gas to -260° F, condensing its volume 600 times for easy shipment overseas. He is part of a team of pioneering engineers who have received support to develop the innovative idea of liquefying gas at sea, in extreme conditions and away from existing infrastructure over the last decade (Shell, N.D.).

Nokia is the world's largest manufacturer of mobile telephones. Venturing at Nokia was triggered to find new avenues of growth. Several teams are active within Nokia under the broad umbrella of Nokia Venture Organization (NVO) which was founded in 1998. The overall aim of these venturing teams is to identify and develop new business opportunities that fall outside Nokia's current focus but are within the scope of Nokia's strategic agenda (Shah et. al, 2008).

New growth opportunities funded by NVO include new wireless services such as accessing office data from mobile phones; playing music and video over wireless devices; and mobile games and entertainment as well as enhancing network capabilities have been very prosperous for NVO (Oakes, 2003).

IBM, Shell and Nokia all have seven commonalities among their corporate venturing:

1. Analyze Necessity
2. Define Objectives and Deliverables
3. Involve a Visionary Senior Executive
4. Commit Resources: Funds, Managers and Organizational Home
5. Develop a Disciplined Governing Mechanism
6. Define the Project Transfer Process
7. Identify and Attract the Right People (Shah et. al, 2008)

CHAPTER 3: INTRAPRENEURSHIP – LEARNING FROM PAST FAILURES

The following example of a failed new venture by Boeing illustrates the importance of intrapreneurship free of traditional corporate policies.

In 1964, the Massachusetts Bay Transportation Authority (MBTA) was created to manage and oversee all commuter operations in and around the greater Boston region, making the MBTA one of the busiest commuter systems in the country (American-rails.com, 2011). The MBTA was also formed to take advantage of the newly passed federal aid legislation. The MBTA's replacement for the PCC cars, dubbed the "Type 6", entered the design stages in 1969 and was initially designed to be a high performance version of the PCC car. A wooden mock-up of the proposed car appeared in early 1970 which included air conditioning.

Around the same time the MBTA was designing their railcars, the San Francisco Municipal Railway (MUNI) had hired Louis T. Klauder and Associates to design a new type of car to replace their PCC fleet. Klauder’s design was also a high performance version of the MUNI PCC railcar it was replacing.

In 1971, MUNI put out a contract proposal for 78 cars, expecting the price per car to be in the $300,000 to $350,000 range. However, the bids received were from $500,000 to $700,000 per car. MUNI rejected the bids and set out to redesign their cars and eliminate any costly and unnecessary parts of the design.

The UMTA became concerned with the high costs of the MUNI car design and the consideration that the MBTA was looking for a fast solution to one of its more troublesome railroad lines (the Green Line), and was looking at importing a Düwag car from Europe. The UMTA, in an effort to promote standardized equipment at a reasonable price for San Francisco, Boston, and any other city that may be interested in new cars, created the Boston - San Francisco (BSF) Committee in early 1972. The BSF Committee provided oversight by taking MUNI’s original design and making it compatible for both the MUNI and MBTA systems. This involved a number of design compromises with the purpose of saving money.

Other cities expressed varying degrees of interest in the program initially, namely Philadelphia, Pittsburgh, Newark, Cleveland, and El Paso, Texas, Mexico City and Toronto. Although all of them would eventually drop out leaving the MBTA and MUNI to design their own car.

The BSF Committee finally completed the design of the "United States Standard Light Rail Vehicle" (LRV) with sufficient concessions on both sides so that the car would function in both cities. However, the resulting design did not totally please either city (Moore, 1998).

3.1 Boeing-Vertol’s Mass Transit New Venture

In the early 1970s, with the Vietnam War coming to a close, government defense budget cuts, and the United States in a recession, Boeing carried out major internal restructuring by eliminating some divisions and creating others. The result was the formation of three largely autonomous companies: Boeing Commercial Airplane, Boeing Aerospace, and Boeing-Vertol for helicopters. Its Commercial Airplane Division remained the largest in the company (Pike, 2011).

In addition to restructuring, Boeing attempted diversification from traditional government and defense contracts with the hopes of keeping prosperous profit margins and steady work for its employees. The goal of diversification was to add less cyclic - or counter-cyclic programs to Boeing’s main product line or airplanes. The enthusiasm for new ventures reached a crescendo in the operating units of Boeing when the Office of Corporate Business Development (OCBD) was formed to aid in focusing these efforts.

The OCBD was a small think tank headed by Henry K. “Bud” Hebeler with a staff of eleven and had a two-pronged charter. The charter included the development of a ten-year business plan which was updated annually for presentation to the Executive Council. The second part of the charter was to make independent assessments of the projects being developed by the operating divisions. Incredibly, this was the first time in the company’s history that such a plan had been instituted.

The most significant projects in the diversification wave included light rail transportation, small automated people movers, commercial hydrofoils, energy systems, urban planning, service industries, waste water purification, desalination systems and property development (Bauer, 1990).

The light rail new venture was championed by the Boeing-Vertol Division in 1973 and was awarded the contract to build a standardized light rail vehicle for $63 million. MUNI and the MBTA ordered 80 cars and 150 cars respectively. The orders were later expanded to 100 and 175 respectively. The Southeast Pennsylvania Transit Authority (SEPTA) and the Greater Cleveland Regional Transit Authority (GCRTA) came close to ordering the cars from Boeing but backed out at the last moment and bought their new cars elsewhere (Mack, 2011).

David Phelps, manager of rail programs for the American Public Transit Association in Washington, D.C. said that Boeing was chosen for the job because it was the lowest bidder that met the necessary qualifications. General Electric Company was the highest bidder at $99 million (Sullivan, 1998).

The UMTA, through the BSF Committee's railcar design standardization was a major cause of problems to Boeing-Vertol. The compromised design coupled with Boeing-Vertol's rail system inexperience led to a myriad of problems. These problems cost Boeing-Vertol, MUNI and the MBTA millions of dollars along with premature retirement of the vehicles.

At first, the rail cars earned high marks from riders in Boston for smoother, quieter, more comfortable rides with fewer "screeches" on curves. But rampant design flaws brought nothing but dismay to transit officials as the new LRV's were problematic from their very first days. They suffered from derailments on tight curves, electrical shorts, failure of the car's motors, and multiple issues with the complicated door system. Because of these failures, the MBTA typically had less than 50% of the fleet available for the first few years of service and MUNI did not have their full fleet operational until 1982, which was nine years after contract award. The multitude of continuing problems resulted in the Boeing-Vertol cars having a very poor mean time between failures (MTBF) (Mack, 2011). At first, the MTBF was a very unsatisfactory 600 miles but improved to between 1800 – 2000 miles in 1982. This was still considered very poor when compared to the German-built railcars in San Diego which had a MTBF of 28,300 miles (Sullivan, 1998).

The continuous malfunctions soon escalated to a major political and public relations nightmare as the rail car problems became more apparent to the MBTA and more importantly, the general public. The MBTA was still accepting new cars from Boeing-Vertol, but the cars were falling out of service faster than the MBTA's maintenance staff could repair them. The rail cars proved so technologically complex that they were impossible for the MBTA to maintain (Rodgers, 1996). Additionally, the MBTA could not acquire replacement parts fast enough to repair the disabled LRVs.

In an effort to keep as many LRVs operating as possible, MBTA maintenance crews began cannibalizing some of the disabled cars for replacement parts and instituting a PCC rebuilding program to augment the LRV fleet. The MBTA also forced Boeing-Vertol to make as many as 70 – 80 modifications to the rail cars each year. Transit officials said that the rail cars just couldn’t hold up under the daily wear of transporting thousands of commuters (Sullivan, 1998).

The MBTA’s Green Line, named because it goes through an area called the Emerald Necklace of Boston (Gaffin, 2003) was famous for being the most heavily used light rail line in the country but also became the focal point of a major newspaper story. A reporter and a photographer managed to get into a section of the Green Line's subway which was not in use at the time and found it full of cannibalized cars which had been abandoned in the tunnel. They were in the tunnel to help prevent the riding public from seeing the sheer number of brand-new, but heavily cannibalized LRVs. The MBTA had been towing the cars into the subway during the middle of the night when the subway was closed to the public. The story and photographs brought the problems with the LRV into the public eye for the first time. After the story broke, out of service LRVs began to appear in several storage yards which were easily viewed by the public, though this may have simply been due to the ever-increasing number of disabled cars (Lampariello, 2011).

As the public on the east coast became increasingly aware of the ongoing LRV problems, MUNI was experiencing unique west coast problems caused by the standardized design. The San Francisco cars needed stairways for ground-level boarding on the surface parts of their rail lines but also needed the stairs stowed to convert for high-platform operation in the subway underground. This became a passenger flow problem in San Francisco. MUNI could only use the two center doors on the LRVs in the subway. The front end of the railcars curved away from the platforms resulting in an excessive, unsafe gap which prevented passengers from safely boarding or exiting the cars. Having doors that could not be used underground caused major passenger congestion and inconvenience (Dilger, 2008). This was another design compromise as the narrow front end was required by Boston so that the LRV could navigate the tight curves in their 1897-vintage subway as shown in Figure 1 below.

Figure 1. Boeing-Vertol LRV with Rounded Corners and Doors

In addition, MUNI passengers experienced brakes sticking and rusting thin metal roofs that leaked. Passengers sweltered on hot days since the MUNI cars were not air conditioned and worst of all, the rail cars wheels worked loose. "They are scrap", MUNI spokeswoman Maggie Lynch said of the cars that cost millions in renovation and repairs. Unlike the cable cars, few people will look back fondly on Boeing's LRVs, which were troublesome since they were new and a continuous nuisance in the mid-1990s as public confidence bottomed out (Leichuk, 2002).

3.2 Boeing-Vertol's Mass Transit New Venture Failure

By 1979, after becoming increasingly frustrated with the ongoing failures of the LRVs, the MBTA successfully sued Boeing-Vertol for financial damages, the cost of repairs and modifications to several cars. The MBTA also negotiated the ability to reject the last 40 cars of their order.

What led to the Boeing Vertol Mass Transit New Venture failure? The main reason, I believe, was the lack of leadership that understood the details and relationships of light rail cars and mass transit. Other factors included improper planning to diversify into unfamiliar markets from core competencies to overcome economic pressures; ignoring historical lessons of previous mass transit designs and lessons learned; using unproven technology; and a lack of commitment to thoroughly test each subsystem.   I also believe that there was a certain level of arrogance and narrow-mindedness in believing that aerospace policies and procedures trump true understanding of different technology's requirements and specifications.

Before attempting this new venture, Boeing Vertol would have been better prepared to succeed had they analyzed the following:

- The economics of light rail vehicles and other transit systems
- Practical means of achieving mass transit capacity requirements
- Elements of safe design
- Failure modes and effects in light rail vehicles
- Integration of mean times to failure into a model of system dependability
- Specific criteria for light rail vehicle system components
- The dynamics that affect the design, size and layout of vehicles
- A disciplined process and continuous commitment to weight and cost control
- Trade studies between proven vs. new components and designs
- Commercially realistic performance specifications
- A commitment to careful system optimization
- Willingness to support experiments that clarify uncertainties
- A willingness to "break the paradigm" of existing project culture
- Engineering and designer training for a new venture (Anderson, 1996)

The six most prominent factors that lead to Boeing-Vertol's mass transit failure, in order of importance were:

1. Lack of leadership that understood Mass Transit
2. Lack of specific criteria for design of light rail vehicle system components
3. Unrealistic performance specifications
4. Ignorance to the elements of safe mass transit design
5. A weak and undisciplined commitment to weight and cost control
6. Failure to understand the failure modes and effects in light rail vehicles

During Boeing-Vertol's Mass Transit New Venture period, Thornton "T" Arnold Wilson was the company President, Chief Executive Officer and Chairman of the Board. Wilson, as well as Boeing, was world renowned for aerospace and aeronautic expertise but Wilson also had an intuitive feel for his company's larger interests. He never liked diversifying if it meant moving the company onto ground it knew less well or not at all. Wilson knew that the leadership before him did not understand the intricacies and dynamics of mass transit and that Boeing had no business in this new venture. However, the economic despair at Boeing in particular and the United States in general during the years immediately following the Vietnam War, left the Boeing executives before Wilson with seemingly little alternative than to venture into commercial and alternative ventures (Boeing, 2011).

Robert R. Kiley, who was the Chairman and Chief Executive Officer of the MBTA recalled his encounter with "T" Wilson in 1975. "I was alone in my office in Boston, and a guard downstairs called to say that a man named Wilson was there and wanted to see me. When I discovered it was T. Wilson, Boeing's CEO, I went down and brought him to my office. He was upset about what happened, noting how sorry he was not to have stopped this move by Boeing into a technology it knew nothing about. He made clear his feelings that Boeing should not stray from the business it knew. He said, "Mr. Kiley, my only interest is preserving my company's good name. I'll do whatever you want us to do". He offered, in effect, to fix the trains or, failing that, repay the MBTA's investment – about $45 million in mid 1970s dollars". (Newhouse, 2007). The lack of leadership that understood mass transit proved to be a very costly venture for Boeing-Vertol.

Had Boeing-Vertol been more experienced in mass transit, they might have recognized the ambiguity and unrealistic performance specifications levied from the UMTA. In an attempt to standardize light rail cars, the UMTA tried to reduce cost through a joint procurement and to develop a standard light rail vehicle that could be used by multiple cities. This standardization attempt by the UMTA actually caused ambiguity and a lack of specific design criteria for the LRV system components. The UMTA's attempted merger of two specific sets of requirements from different needs resulted in more complex and unrealistic design requirements. The UMTA's compromised design proved to be Boeing-Vertol and the rail cars' major drawbacks, as subsystem after subsystem produced headache after headache (Vantuono, 1996).

Not having past experience in previous mass transit design and specifications, Boeing relied on its core-competencies and used past aerospace and aeronautics engineering practices to design the LRVs to the best of their in-house capabilities. The railcar doors were designed and manufactured out of materials that could withstand the stresses of supersonic flight but could not withstand the kicks of passengers (Green Dividend, n.d.). State Rep. Lincoln P. Cole Jr., Vice Chairman of the MBTA's advisory board, said "Boeing was not in the trolley car business originally, so it's not surprising that their first try wasn't that good. I heard the doors in those cars have 4000 moving parts; you have to figure something will go wrong" (Wiltshire, 1979). The doors actually had 1300 parts but would not close properly and would give false signals that interrupted operations. The door design was based on Boeing's previous aeronautic and aerospace experience where a plug door is designed to seal itself by taking advantage of pressure difference on its two sides which is typical on pressurized aircraft. The higher pressure on one side forces the wedge-shaped door into its socket, making a good seal and preventing it from being opened until the pressure is released. These types of doors, however, are usually limited to vehicles that make infrequent stops as the door operation is slow and mechanically complex. Figure 2 below shows an improved design of the plug type door that did not recycle when it is accidentally closed on someone or something. The wide rubber strips are soft enough that trapped objects can be pulled through. Unfortunately, it was not until the 1990s when all passenger cars were retrofitted with more reliable bi-fold doors (Moore, 1998).

Figure 2. Boeing-Vertol's Redesigned Plug Type Door

Proper Failure Modes and Effects Analysis (FMEA) using mass transit requirements instead of the familiar defense standards could have also greatly improved the success of the New Venture. FMEA is used to analyze potential reliability problems in the development cycle of the project, making it easy to take actions to overcome reliability issues, mitigate risks and enhancing the reliability through design. FMEA is used to identify actions to mitigate the analyzed potential failure modes and their effect on operations. Anticipating these failure modes, by being familiar and experienced with the specifics within the mass transit domain, needs to be carried on extensively, in order to prepare a list of maximum potential failure modes (Visitask, 2011). The defense industry standard of concurrency was also utilized out of mass transit inexperience.

"Concurrency" in defense programs is the overlapping of development and production of systems and has long been a controversial Pentagon practice. Not surprisingly, inventing something while beginning to build it, particularly something as complex as a modern warship, aircraft, or combat vehicle, introduces the risks of schedule delays and cost overruns. At the same time, the rapid fielding of a still-to-be-perfected system can create or preserve an advantage on the battlefield; it's the technological equivalent of getting there "the fastest with the mostest." While there's no way to eliminate the risks, the Defense Department has often felt that the rewards of concurrency outweighed the risks. "Concurrent development and production of weapons systems has been emphasized during wartime or periods of national emergency, when a consensus readily supported the acceleration of high-priority weapons systems." Historical examples included depth charges and nuclear weapons in World War II, the Sputnik-era missile programs of the 1950s, and the introduction of "smart" weapons from the 1960s through the 1980s (Donnelly, n.d.).

As in previous high-priority defense projects, manufacturing and testing of the railcars were performed simultaneously instead of fully testing the railcars before delivering them to the customer and entering them into service. Fully testing the railcars before delivery would have uncovered many of the defects that plagued the MBTA, MUNI and Boeing-Vertol.

3.3 Lessons Learned from Boeing-Vertol's Mass Transit Failure

Boeing-Vertol's mass transit new venture did not successfully "forget, borrow and learn" from Boeing's core business units. The new venture did not forget what made Boeing-Vertol successful in the past and establish the elementary differences between mass transit and aeronautics/aerospace. The core business assets that were borrowed were the established policies and procedures of the foundational defense contracts. As such, the status quo on the range of issues from needed competencies, planning and budgeting, business performance assessment, metrics, etc. were not challenged and adapted to the new venture.

In hindsight, Boeing-Vertol learned about mass transit too late. Robert Kiley said, “Some obvious techniques were overlooked in this zeal for applying modern technology to streetcars…One technique that was overlooked…and it’s surprising that it didn’t occur to someone to go that route, is a prototype. It wasn’t done, and I think it’s the most crucial mistake made in the program”. Unlike previous rail car programs that took an average of six years of work before the initiation of full scale service, little research on the LRV was conducted. Probably Boeing’s biggest mistake was that the company felt that it was not in their commercial interest to license known, proven designs. If Boeing had used proven technology for the LRV, many of the car’s problems may never have existed. As an example, the Chicago Transit Authority (CTA) also received LRVs. However, the CTA order differed from MUNI and the MBTA in that they specified General Electric camshaft controllers, which were derived from the PCC program in the early 1960s (the MUNI and MBTA LRVs had the new solid state “chopper” control). The CTA cars had no major problems, indicating that the LRV’s problems stemmed more from the use of unproven technology, and insufficient vehicle testing, not Boeing’s ability to manufacture a rail vehicle (Moore, 1998).

In fact, as of 2011, Boeing cars are still in use after more than thirty years. Among the reasons why the company left the subway business was that post-Vietnam War military build- up provided Boeing with far more lucrative military contracts.

3.4 Comparison to Other Recent Failures

A surprising comparison to Boeing-Vertol’s mass transit new venture failure can be made with Goldman Sachs’ recent contribution to both the US housing and financial crisis of the 2000s.

Goldman Sachs ventured from a traditional domestic organization into an established global banking power by incorporating junk bonds and private equity as well as globalizing operations (Friedman, 2009).

Goldman Sachs leaders, in conjunction with leaders of other investment banks, successfully lobbied to eliminate effective limits on the amount of leverage the largest investment banks could use. In 2004, under pressure from Goldman Sachs in particular, the Securities and Exchange Commission (SEC) removed the 12 to 1 debt to capital ratio it had previously imposed. The SEC gave the five largest investment banks (Goldman Sachs, Bear Stearns, Merrill Lynch, Lehman Brothers and Morgan Stanley) a special exemption so they could use their own risk models to determine their capital requirements. In some cases the debt to capital ratio was as high as 40 to 1. This new SEC deregulation enabled the investment banks to expand their businesses through borrowing, but left them fatally undercapitalized when they suffered losses (Ritholtz, 2009).

Goldman Sachs contributed to both the US housing crisis and the financial crisis by selling subprime, mortgage-backed securities. From 2001 to 2007, Goldman Sachs sold $135 billion of bonds backed by risky mortgages. Carl Levin, the Democrat Senator chairing the Senate Permanent Subcommittee on Investigations, stated that "From 2004 to 2007, in exchange for lucrative fees, Goldman Sachs helped lenders like Long Beach, Fremont and New Century, securitize high risk, poor quality loans, obtain favorable credit ratings for the resulting residential mortgage backed securities (RMBS), and sell the RMBS securities to investors, pushing billions of dollars of risky mortgages into the financial system (Levin, 2010). Within 18 months after Goldman Sachs sold subprime securities to investors, one sixth of the mortgages underlying the bonds had defaulted. Goldman Sachs subprime bonds related to the losses and foreclosures suffered in the financial crisis (Sloan, 2007). This also assisted in snowballing the US housing crisis into a full-blown financial crisis. By 2007, the US housing bubble had already started to deflate. By creating packages of securities, Goldman Sachs allowed investors to bet on loans that had already been made. In this way, Goldman Sachs contributed to a whole new wave of speculative activity that ended with the near-collapse of the global financial system and government bailouts of banks (Nocera, 2010).

Goldman Sachs leaders defrauded investors and were charged as such on April 15, 2010 by the SEC. Leaders such as Executive Director Fabrice Tourre broke the law and committed fraud when they sold clients a complex investment linked to the value of home loans that was secretly designed to fail (Goldfarb, 2010).

Comparing the Goldman Sachs fiasco to Boeing-Vertol's mass transit new venture failure underscores the "forget, borrow and learn" scenario with organizational commitment and strong, ethical leadership. Both Goldman Sachs and Boeing-Vertol did not challenge the status quo on the major issues of needed competencies, reporting relationships, decision rights, planning and budgeting, business performance assessment, metrics, shared values, and shared assumptions about success. Most importantly, they both did not embrace the differences between their new ventures and core business which resulted in financial loss for mismanaging their new venture and inflicted great financial loss on others.

CHAPTER 4: CORPORATE INTRAPRENEURSHIP

The intrapreneurship process is based on research and lessons learned from past intrapreneuring successes and failures. Figure 3 illustrates the overall process.

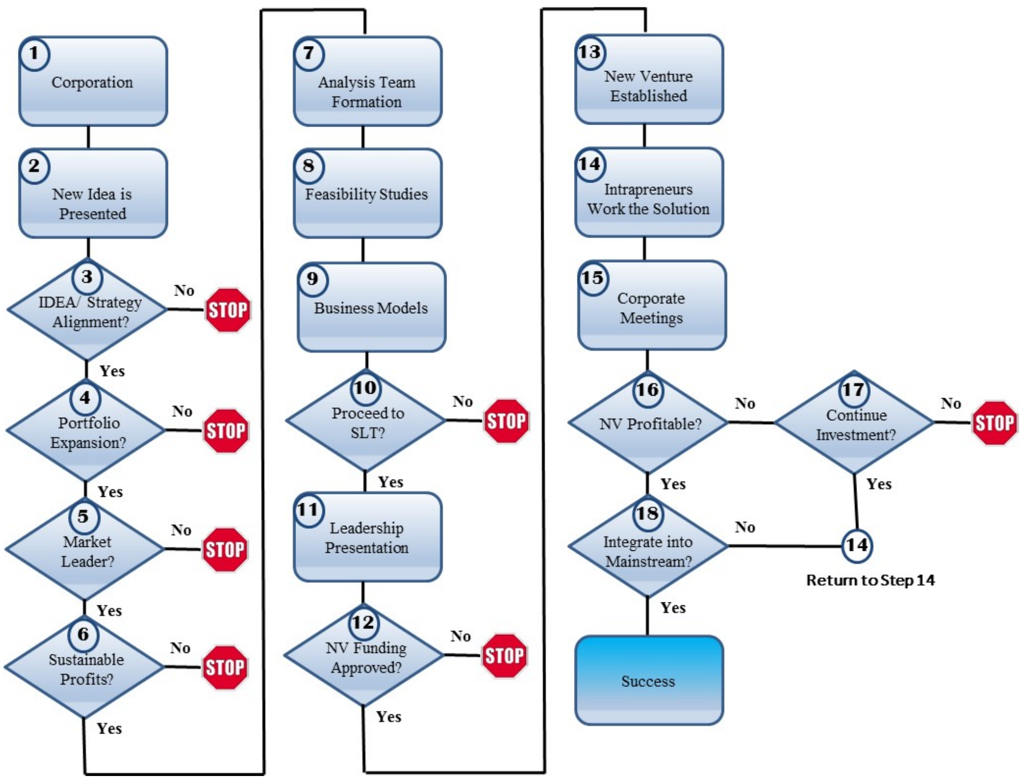


Figure 3. Intrapreneurship Process

Figure 4 illustrates that the intrapreneural process begins with the corporation.

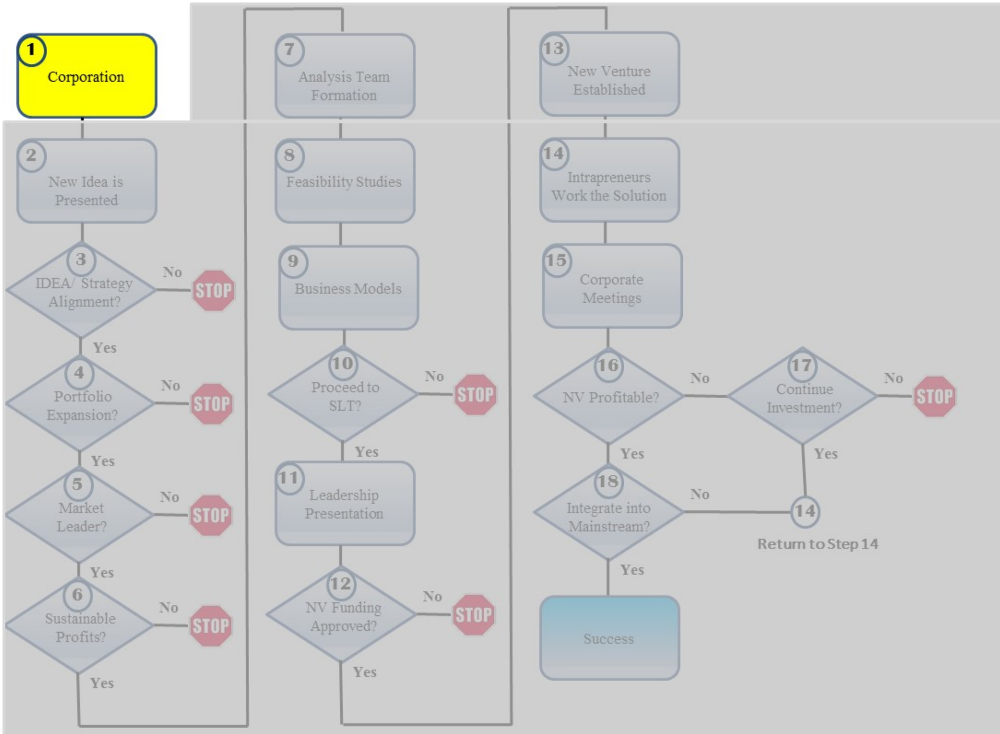


Figure 4. The Intrapreneuring Process Must Start with the Corporation to be Successful

However, a new business venture with high growth potential rarely coexists gracefully with the most closely related established business unit within the core company. The unnatural combination creates three specific challenges for the intrapreneurs of the new venture:

- Forgetting
- Borrowing
- Learning

The new business venture must *forget* some of what made the existing core business successful, because the new venture and the core business will always have elemental differences. The new venture must *borrow* some of the core business assets—the greatest advantage it has over independent entrepreneurial start-ups. The new venture must also be prepared to *learn* some things from scratch.

Forgetting, borrowing, and learning are monumental tasks. That’s why it’s crucial for a company to leverage the power of organizational design. In building the new venture, corporate leadership must be willing to challenge the status quo on an extraordinary range of issues: hiring, individual performance evaluation, needed competencies, reporting relationships, decision rights, planning and budgeting, business performance assessment, metrics, compensation, shared values, and shared assumptions about success. These three challenges are present throughout the new venture's lifespan, from launch to successful profitability. And they're present all at once, which means tackling them requires an understanding of how they're related. Forgetting and borrowing are at odds, for example, and need to be balanced. A sole focus on forgetting would suggest isolation of the new venture, while a sole focus on borrowing would suggest full integration of the new venture. Also, failure to forget cripples the learning effort. If the new venture cannot leave behind the core company's formula for success, it will not find its own. To build a foundation for success, the new venture must forget the core company's business model and *learn* its own. The new venture must answer the fundamental questions that define its venture—Who are our customers? What value do we offer? How do we deliver that value? These answers should be different from the core company's established businesses.

Learning is about changing behavior. It is not enough to establish a new venture that can speak the lingo of the new venture but acts identical to the core company. As Ray Stata, cofounder of Analog Devices stated, "I came to the conclusion long ago that limits to innovation have less to do with technology or creativity than organizational agility. Inspired individuals can only do so much. Emphasis must shift from ideas to execution and from leadership excellence to organizational excellence" (Govindarajan, 2005).

Corporate new venture champions and intrapreneurs must keep the "forget, borrow, and learn" scenario fresh and bridge the gap between corporate executives and those with ideas for new ventures. Most corporations are very reluctant to devote management attention, resources, time, or talent to rolling the dice on new ventures and especially tapping into their "A-teams" to run them. Engineering Managers must also assist in overcoming a typical corporation's success measures by staffing to "build an empire", which is the classic measure of stature. Staffing should come after clarity (Deutschman, 2005).

In building a new venture, Engineering Management can champion the following:

- Understanding the requirements of the new venture
- Defining the customers for the new venture
- Determining the value the new venture will provide to customers
- Determining what sets the new venture apart from the competition

- Fulfilling the needed competencies for the new venture that are missing from the core business unit
- Assisting in business performance assessment, planning and budgeting
- Establishing shared values and shared values about success between the start-up team and corporate
- Determining metrics
- Assisting in changing the behavior of the new venture team from status quo

Perhaps the greatest contributions corporations can make to new ventures are to ensure due diligence and adequate and appropriate research and planning *before* a new venture is officially formed. This due diligence can include research into past intrapreneuring new venture successes and failures to learn what was and what was not successful.

Each step in the intrapreneural process will be examined and described through the use of an example idea which focuses on a group of mid-level engineers in a large engineering based industrial corporation who desire to use their engineering, procurement and construction (EPC) knowledge and enter a new venture of sustainable and renewable energy.

Figure 5 highlights that ideas for new ventures can only be successful after corporations have intrapreneural policies and procedures in place that encourage promoting intrapreneurship.

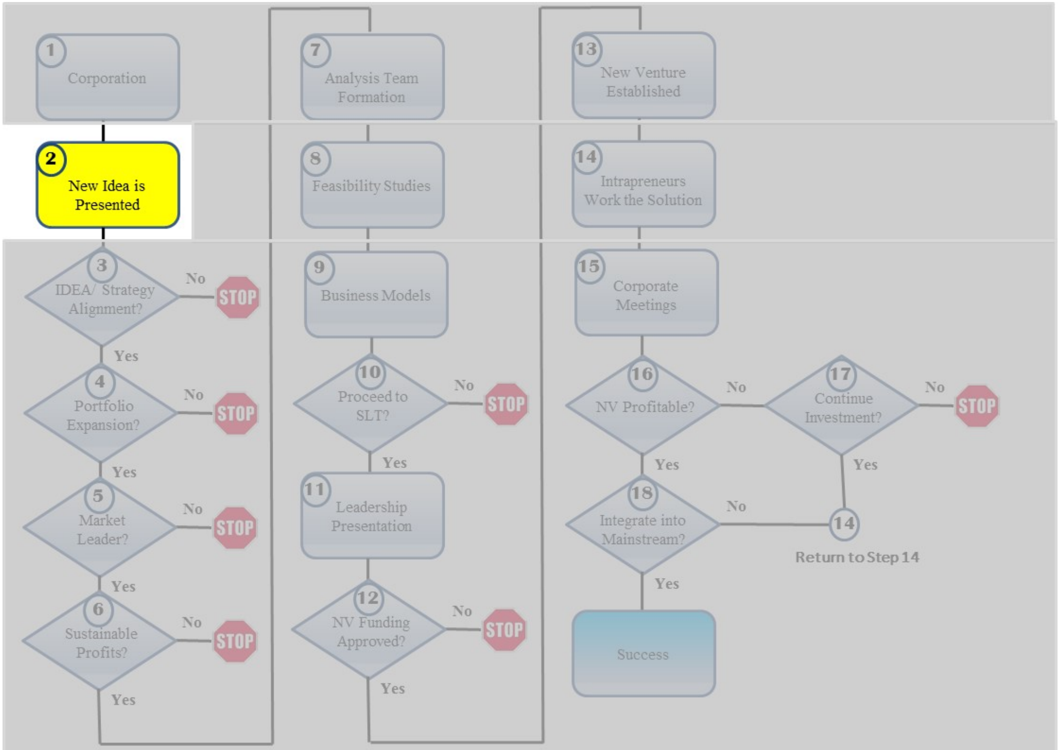


Figure 5. New Venture Idea Presented by a Corporate Intrapreneur

In this example, the idea is a means of providing sustainable renewable energy to rural agricultural districts that evolved from large defense and aerospace projects involving fuels, energy and the increasing demand for conservation coupled with the engineering challenges of a renewable yet sustainable energy program. This idea surfaced and flourished since power systems traditionally have little energy storage capability. Power systems must operate such that the aggregate output of all generators meet network demands as the demand changes in real time.

Although the United States power grid generates more than 1,000 GW of electricity to meet peak demand, its total instantaneous storage capacity is less than 50 GW. The traditional approach to bulk storage of electric power is by mechanical means such as pumped-storage hydroelectric and compressed air-turbine generation. However, bulk storage has proven very expensive and usually not ideal for urban load center locations where storage is most effective and profitable.

There are many technical challenges in supplementing conventional sources to supply a regional grid servicing distant markets. In addition, renewables are often dispersed, remote, and intermittent.

However, where the cost of distributing power exceeds the cost of generation, as can occur in rural areas, renewables would be economical if the availability to meet demand was reliable. In the High Plains of the United States, wind resources are fairly constant, but even so, the wind speed is not reliable enough to satisfy real-time local sales demand, unless excess capacity is installed. Moreover, in low wind, all units operate less efficiently. In areas with insufficient wind reliability or difficulty connecting to the grid, our solution approach is to store or find other uses for the excess power produced in high winds. This electricity can be used in processes that tolerate interruptible and variable supply. For a fully integrated system, excess wind can power can be used in the production of biofuels from local feedstock. This will maintain local power supply reliability in periods of sparse wind and perhaps, support export or local use as fuel.

Much organic waste is produced in agricultural areas, ranging from animal manures to straw. Anaerobic digestion (AD) exothermally converts such feedstock to biogas, a mixture of methane, carbon dioxide and other gases. It is readily stored and conveyed like liquid or gas fossil fuels. Turbines and internal combustion engines have been developed that burn this low calorie fuel to produce electricity. Converting biogas to electricity can be used for both local distribution in low wind periods and also to run AD facility equipment such as stirrers and pumps. When the power demand from the AD turbines is low or non-existent, the excess continuously produced biogas can heat temperature-sensitive digesters. In high wind, the excess power and biogas can be used to clean and desiccate the biogas, and remove the CO_2 fraction.

The Intrapreneurship process from a large corporation's new venture inception will be used to develop a solution to harness the wind power of the Great Plains to meet local demands and store excess power when peak load is less than peak energy output. This compensates for the variable availability of wind electric power and limited grid transmission capacity. The proposed solution can accomplish these goals by developing an integrated renewable energy technology using wind, animal and agricultural wastes to produce a more transportable and storage able end-product – syngas. Syngas can also be exported using the current local and national pipeline and transportation infrastructures and thus avoid placing additional burdens on the electric grid.

Figure 6 illustrates the corporate decision gates that are part of the intrapreneural process. In the dissertation example idea, the renewable energy idea is strategically aligned with the corporation's objectives (step 3) since the corporation has energy projects in its portfolio. The renewable energy idea has the potential to expand the corporation's portfolio (step 4) by offering an integrated renewable energy solution. The corporation does not currently offer any renewable energy solutions. It is strategically possible that the integrated solution could result in the corporation being a market leader (step 5) with the solution's combined technology. Finally, by targeting rural electric cooperatives with the integrated renewable energy solution, the new venture resulting from implementing the intrapreneural idea could result in substantial sustained profits (step 6).

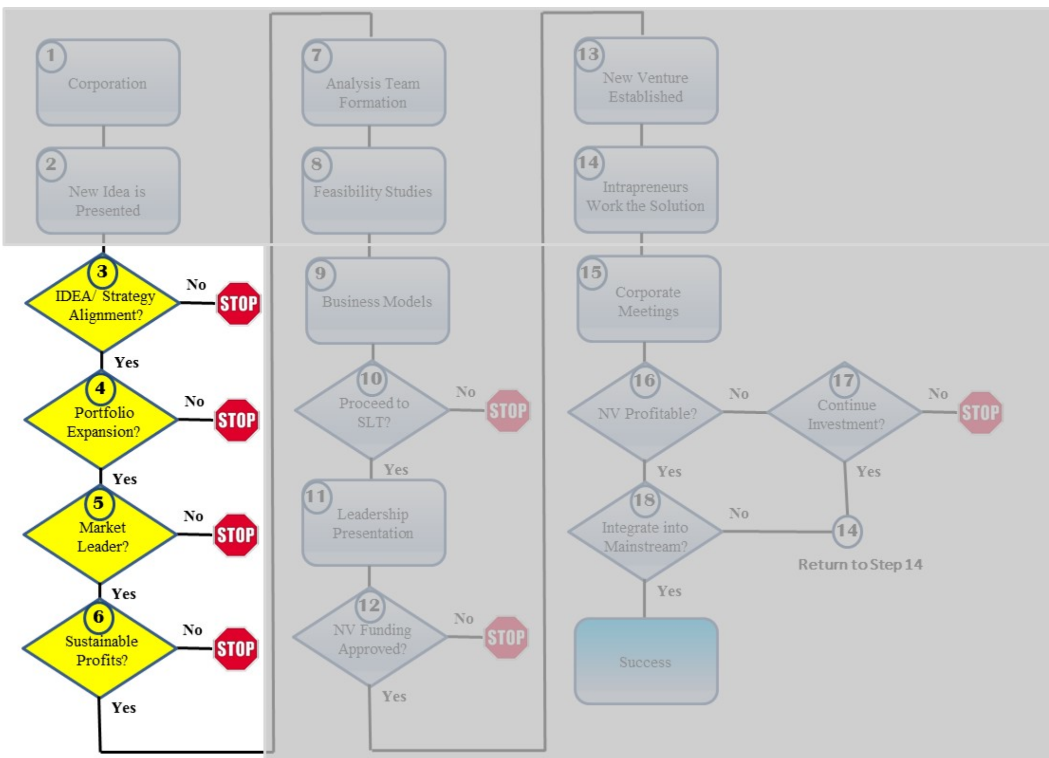


Figure 6. Corporate New Venture Decision Gates to Determine if the Intrapreneural Idea Aligns with Corporate Objectives

By passing all of the corporate decision gates, the idea is acknowledged by the corporation as potentially viable and an analysis team is formed to study the idea in greater detail. The formation of the analysis team is highlighted in Figure 7.

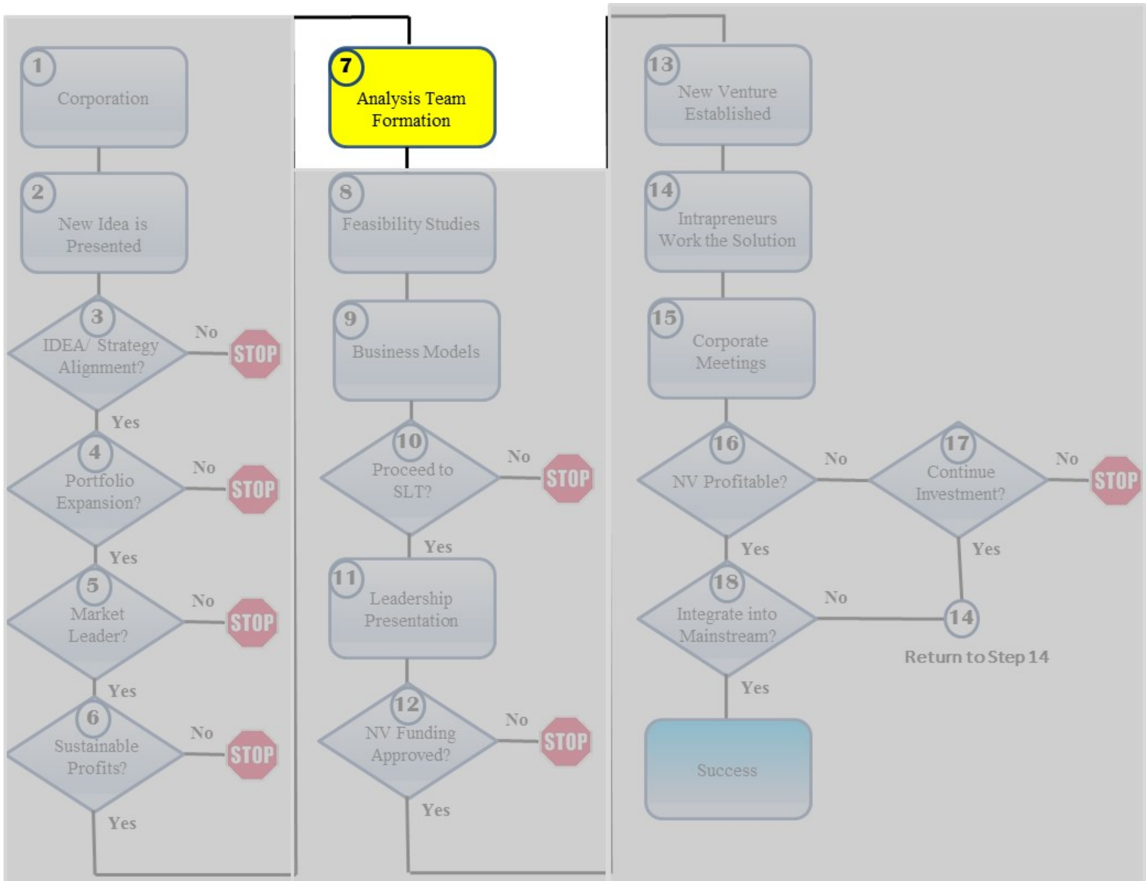


Figure 7. Analysis Team Formed After the Idea Passed the Initial Four Corporate Decision Gates

CHAPTER 5: NATURAL RESOURCES FEASIBILITY STUDY

As shown in Figure 8, after the analysis team is formed, feasibility studies will be conducted to investigate the variables, factors and potential benefits of an integrated renewable energy solution and determine if the investment of corporate resources will yield a desirable result. The first area analyzed in providing sustainable renewable energy to rural agricultural districts is a feasibility study on the Great Plains Natural Resources.

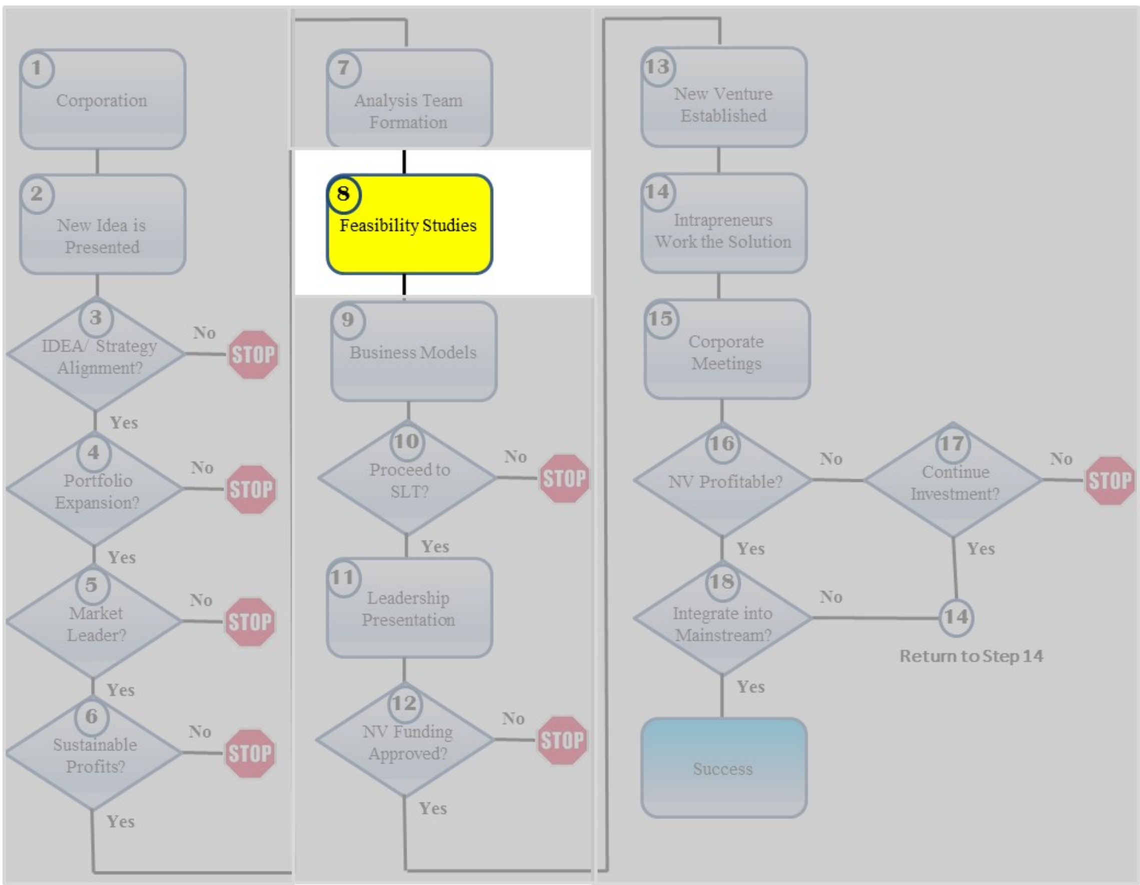


Figure 8. Feasibility Studies are Used to Investigate the Variables, Factors, and Potential Benefits of the Idea.

The Great Plains stretches across parts of ten states – Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas and Wyoming (See Figure 9). The Great Plains consists of 376 counties with a land area of 533, 100 square miles, about one-fifth of the entire lower forty-eight states but only approximately 3 percent of their population (Phelps, 2009).

Historically, the Great Plains were divided into three zones: eastern tall grass prairie, a broad transitional mixed grass zone, and the western short-grass plains (See Figure 10). Today these three grasslands zones are now the eastern corn and soybean zone, the Plains soft and hard wheat belt, and the western cattle rangelands. Their 334 million annual tons of wheat, oats, barley, rye, sorghum, and corn are roughly 25 percent of the world's total production of these grains.

Figure 9. Map of the Great Plains (University of Nebraska, 2013).

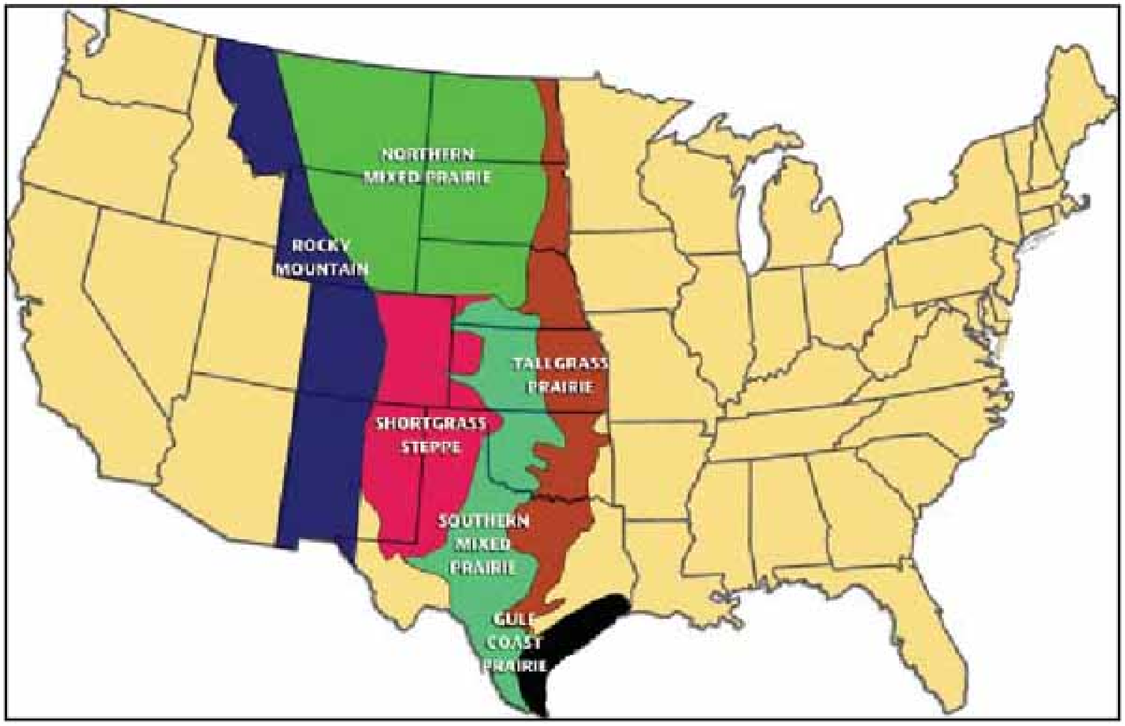


Figure 10. Great Plains Grasslands.

(a) **(b)** **(c)**

Figure 11. Great Plains Grasslands. (a) Short Grass. (b) Mixed Grass. (c) Tall Grass (Pieper, 2005)

5.1 Wind Energy

The windiest spots in the United States are off the coasts, in the mountains, and through the Great Plains, where a band of strong winds stretches from North Dakota to Texas. According to the American Wind Energy Association (AWEA), the top ten states possessing the best wind energy are as follows (Phelps, 2009):

1. North Dakota 2. Texas 3. Kansas 4. South Dakota 5. Montana

6. Nebraska 7. Wyoming 8. Oklahoma 9. Minnesota 10. Iowa

The top eight states are within the Great Plains. The National Renewable Energy Laboratory (NREL) has published data on wind farms generating more than 20 MW and installed after 2000 (Denholme et. al, 2009). Appendix A contains the tabulated wind farm data from NREL by state. Figure 12 below illustrates the Great Plains Wind Farm Projects.

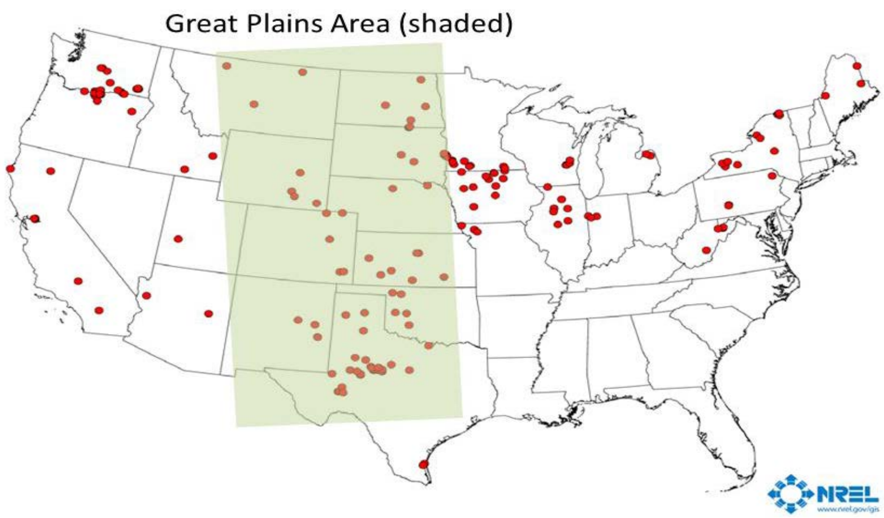


Figure 12. Plains (Shaded Area) Wind Farm Projects by State (Denholme et. al., 2009).

Although North Dakota is recognized as having the best wind resources in the country, the North Dakota Department of Commerce has stated that there are many issues that need to be addressed prior to significant wind energy development. The single biggest constraint is the state's existing transmission grid. North Dakota currently exports nearly 60 percent of the power generated within the state, and it is likely that most wind generated electricity will also be exported. Utility experts agree that additions to the transmission grid will be necessary for significant generation expansion in the state, regardless of the fuel source (ND DOC, 2013).

Johnathan Hladik, energy policy advocate with the Center for Rural Affairs (CFRA), said the biggest hurdle right now with renewable energy is getting it on the grid due to a lack of high voltage transmission lines. Less than 1% of the nation’s high capacity transmission lines are located in the states with the most wind-energy potential. Historically, lines originated at one large power plant (fossil, hydroelectric or nuclear) and were aligned to serve one large municipal area, while smaller lines were installed in rural areas.

Appendix A contains a list of the major Great Plains Wind Farm Projects (>50 MW).

5.2 Great Plains Population

The United States Census Bureau reports that the Great Plains include many counties with declining populations, a high percentages of population aged 65 and older, and net out-migration. The 2007 census shows that 261 of the 376 Great Plains counties had fewer than 10,000 people. 34 counties had more than 50,000 residents and 22 were above 100,000. However, 21 of the 22 counties with populations over 100,000 were located in Colorado or Texas (Wilson, 2009). Figure 13 shows the Great Plains population by county.

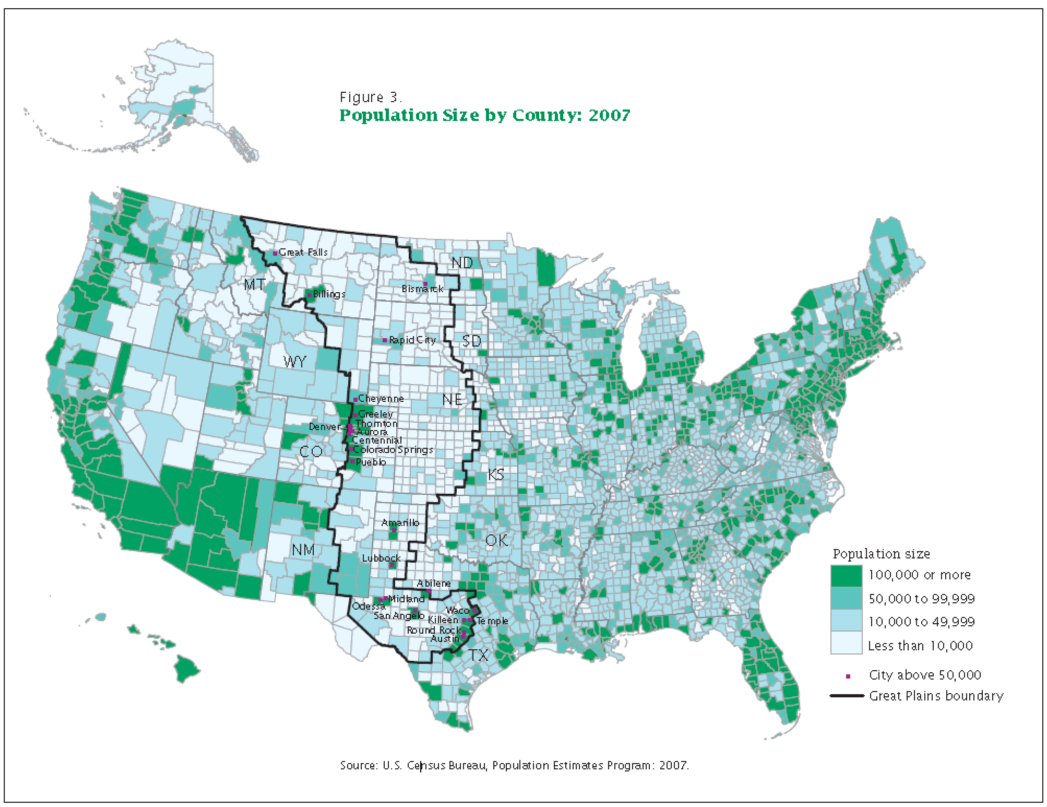


Figure 13. Great Plains Population by Country (Wilson, 2009).

5.3 Vegetative Feedstock

Table 1 summarizes data from the United States Department of Agriculture, 2015 National Agriculture Statistic Service (NASS). Appendix B through Appendix K show details for each state. Table 1 shows the number of farms in each Great Plains state as well as the top crops harvested and the associated United States ranking. Wheat, corn and forage are the most prevalent crops harvested in the Great Plains.

Table 1. Great Plains Agriculture Data and Top Crops by Acres of Harvest (USDA, 2015).

State	No. of Farms	Top Crop	Acres	US Rank
North Dakota[a]	30,300	Wheat	7,767,484	2
South Dakota[b]	31,700	Corn	5,289,110	6
Montana[c]	27,800	Wheat	5,627,463	3
Wyoming[d]	11,700	Forage	1,053,646	22
Nebraska[e]	49,100	Corn	9,087,851	3
Colorado[f]	35,000	Wheat	2,181,967	8
Kansas[g]	61,000	Wheat	9,009,535	1
Oklahoma[h]	79,600	Wheat	4,291,939	4
New Mexico[i]	24,700	Forage	343,032	37
Texas[j]	245,500	Forage	5,069,579	1

[a] See Appendix B North Dakota Agriculture Overview (USDA, 2015).
[b] See Appendix C South Dakota Agriculture Overview (USDA, 2015).
[c] See Appendix D Montana Agriculture Overview (USDA, 2015).
[d] See Appendix E Wyoming Agriculture Overview (USDA, 2015).
[e] See Appendix F Nebraska Agriculture Overview (USDA, 2015).
[f] See Appendix G Colorado Agriculture Overview (USDA, 2015).
[g] See Appendix H Kansas Agriculture Overview (USDA, 2015).
[h] See Appendix I Oklahoma Agriculture Overview (USDA, 2015).
[i] See Appendix J New Mexico Agriculture Overview (USDA, 2015).
[j] See Appendix K Texas Agriculture Overview (USDA, 2015).

The amount of a biomass resource that can be collected at a given time depends on several factors. For agricultural residues, these considerations include the type and sequence of collection operations, the efficiency of equipment, tillage and crop management practices, and environmental restrictions. The latter include needs to limit erosion, maintain soil productivity, and maintain soil carbon levels. Collection methods for agricultural residues are similar to those used in harvesting hay. Different systems have varying capture efficiencies, driving the cost of collection itself to 20 to 25 percent of total delivered cost, typically $5 to $7/ton.

Following grain harvest, residues such as wheat straw and crop stalks, leaves, and cobs (referred to as corn stover), are left in the field. These residues could be collected and combusted to produce energy.

However, only a fraction of the waste should be harvested as the residue protects the soil from water and wind erosion as well as a source of nutrients/organic matter to replenish the soil. Just above one-fifth of the over 100 million tons of agricultural waste annually generated in the United States are currently used.

Although the Great Plains raises more wheat than corn, the energy generation potential is significantly less from wheat straw than from corn stover because wheat straw has a lower energy content. Moreover, fewer tons of wheat straw can be collected per acre. Corn stover contains 5,290 Btu/lb (wet) and 7,560 Btu/lb (dry) whereas wheat straw has 5,470 Btu/lb (wet) and 6,840 Btu/lb (dry). The delivered feedstock corn stover and wheat straw prices include costs of collecting and transporting the residues. The collected cost of corn stover ranges from $20 to $40 per ton while the cost of wheat straw is approximately $50 per ton. Consequently, corn stover typically costs between $1.89 to $3.78/MMBtu, and wheat straw costs about $4.57/MMBtu (LMCO, 2010).

Corn stover bales typically have initial moisture content between 49% and 66%, with an average initial moisture content of 56%. The dry matter (DM) density ranges from 87 to 114 kg DM/m3 with an average of 117 kg DM/m3.

Table 2. Estimated Time, Energy, and Variable Cost for Drying Corn Stover Bales to 12% Final Moisture Content with a Gas Burner or a Heat Pump (LMCO, 2010).

Initial Moisture Content (% w.b)	Drying Time (hr)	Heating Energy (kWh/t DM)	Fan Energy (kWh/t DM)	Energy Cost with Burner ($/t DM)	Energy Cost with Heat Pump ($/ t DM)
20	10.4	263	39	10.24	5.86
25	18.1	456	68	17.75	10.16
30	26.8	676	101	26.33	15.07
35	36.9	931	139	36.23	20.74
40	48.7	1228	183	47.79	27.36
45	62.6	1578	235	61.44	35.17
50	79.3	1999	297	77.82	44.55
55	99.6	2514	374	97.85	56.02

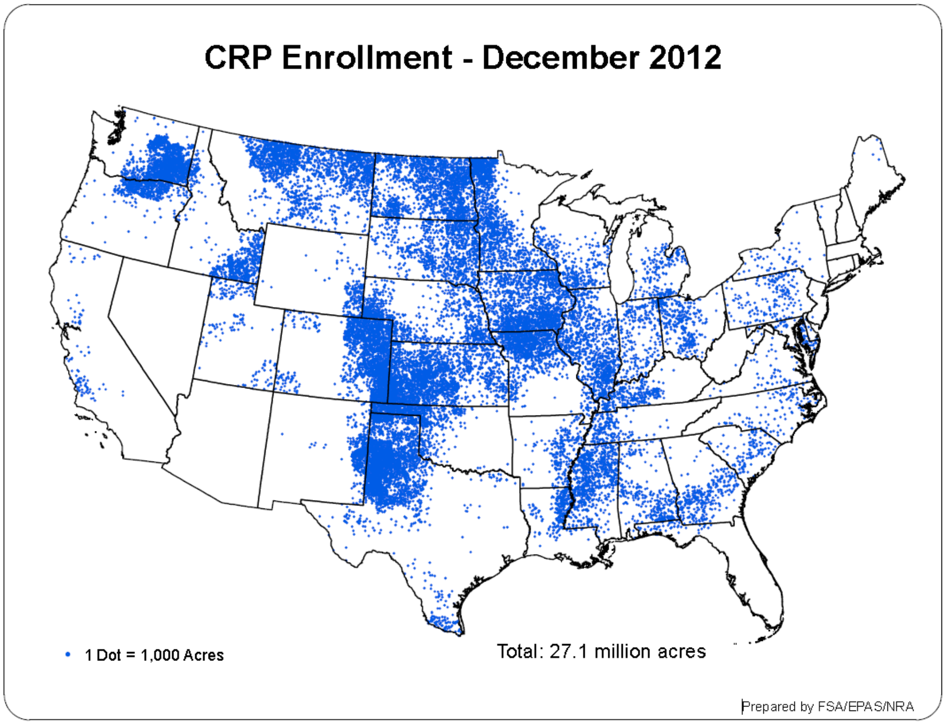
Efficient combustion of corn stover typically requires moisture content less than 12%. Drying can be an energy intensive process in addition to the storage requirements of the dried stover. Table 2 illustrates the typical energy costs of a burner vs. heat pump to dry corn stover.

Energy crops are perennial grasses and trees grown through traditional agricultural practices but are produced primarily for use as feedstocks for energy generation. The Bioenergy Feedstock Development Program at Oak Ridge National Laboratory (ORNL) has identified hybrid poplars, hybrid willows, and switchgrass as having the greatest potential for dedicated energy use over a wide geographic range (EPA, 2007).

Switchgrass (Panicum virgatum) is a common perennial C4 grass widely distributed across North America. C4 photosynthesis is an adaptation that evolved to alleviate the detrimental effects of photorespiration as a result of the gradual decline in atmospheric carbon dioxide levels. This process ensures an efficient capture of CO2 from the atmosphere. On average, crops that use C4 photosynthesis are more productive and use less water and nitrogen than C3 crops (Wang et. al. 2010).

Switchgrass is a dominant occurring plant in the central Great Plains grasslands, with impacts on both the structure and function of these ecosystems and will therefore be the focus energy crop for this analysis. It is an important forage crop in pasture lands, and has been studied extensively over the past two decades for its potential value as an alternative energy source. In recent years, switchgrass has become a model species for biofuel production. Switchgrass was chosen as a prospective biofuel for its ability to increase soil quality, sequester carbon, and its wide range of suitable habitat. Marginal lands that are not currently used for agricultural production may be suitable for switchgrass cultivation. The use of marginal lands for biofuel production is desirable because use of this land minimizes competition with food crops produced on lands of higher agricultural value. This species produces high biomass across a broad range of environments, requires low water and nutrient inputs compared to agronomic species (e.g., corn), and provides environmental benefits for degraded lands (e.g., reduced erosion, increased soil organic carbon).

Cultivation of switchgrass as a perennial energy crop has also been considered for marginal lands currently in the Conservation Reserve Program (CRP). This program, developed in 1985 as part of the Food Security Act, provides compensation for landowners to rest their land from continual agricultural production. A byproduct of removing land from agricultural production is the establishment of permanent grass cover. As of 2012, there were 27.1 million acres enrolled in the Conservation Reserve Program (See Figure 14 below). The CRP program has advanced conservation practices, with estimated decreases in soil erosion of 220 million tons/year. Native bird populations have increased by 2–52% (Hartman et. al., 2011).



.

Figure 14. Conservation Reserve Program Enrollment.

The cost of harvesting switchgrass is similar to most forage crops because switchgrass can be cut and baled with conventional mowers and balers. This makes this energy crop the easiest and cheapest to harvest. Switchgrass has energy content of 6,060 Btu/lb (wet) and 8,670 Btu/lb (dry) and costs range from $35 to $50 per ton. Consequently, switchgrass typically costs between $2.89 to $4.13/MMBtu (EPA, 2007).

In addition to switchgrass for use in combustion, firms such as Great Plains Oil and Exploration encourage growers to raise oil seed crops such as camelina. It can be used as a feedstock for Biodiesel manufacturing. Camelina (see Figure 15 below) is a biodiesel feedstock that is also attractive to growers because of its ability to thrive on marginal land with little fertilizer and water. It can be harvested with conventional equipment and works well as a rotational crop. The oil content of camelina seed ranges from 29% to 39% (Putnam et. al, 1993). The processing residue that is not used for fuel production can be used to make animal feed, fiberboard and glycerin (Priestman, 2008).

Figure 15. Camelina.

Biodiesel is unusual among biofuels in that it is almost interchangeable with conventional diesel fuel. Most biodiesel production uses trans-esterification processing since it is relatively inexpensive and technologically simple. Trans-esterification reacts the fats and oils in the feedstock with alcohol to produce the biodiesel and glycerol. Figure 16 illustrates the process. Moreover, net energy balance analysis indicates that biodiesel yields more than three times the energy in combustion it than it takes to produce it.

Currently, biodiesel production and consumption is a small fraction of the country's diesel market. In order to displace a larger percentage of conventional diesel fuel, a huge shift in agricultural resources would be required that would impact the global food supply. Thus, while biodiesel processing is relatively inexpensive, the adverse impacts of expanding feedstock production could be severe. Figure 17 compares some potential oil source crops.

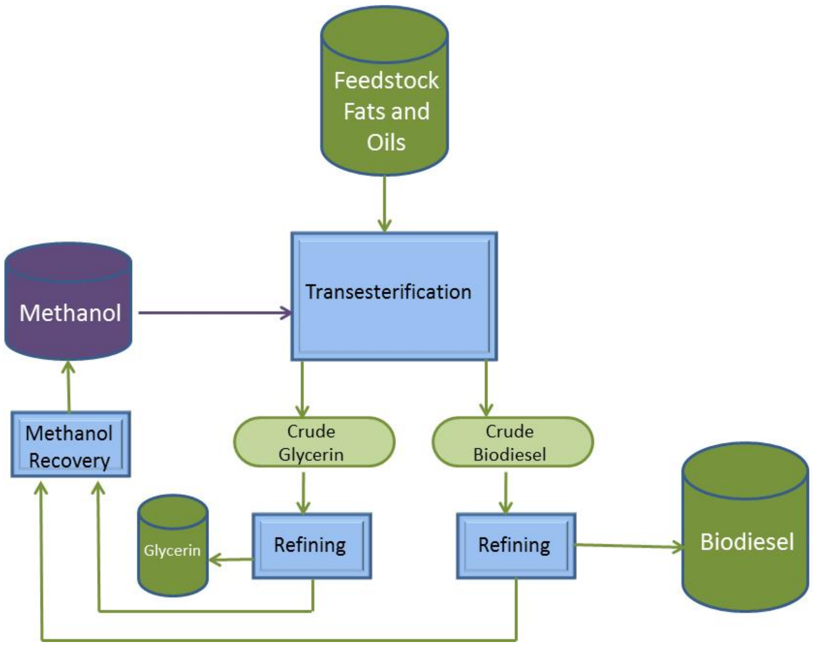


Figure 16. Biodiesel Transesterification Flow Diagram (Tabak, 2009).

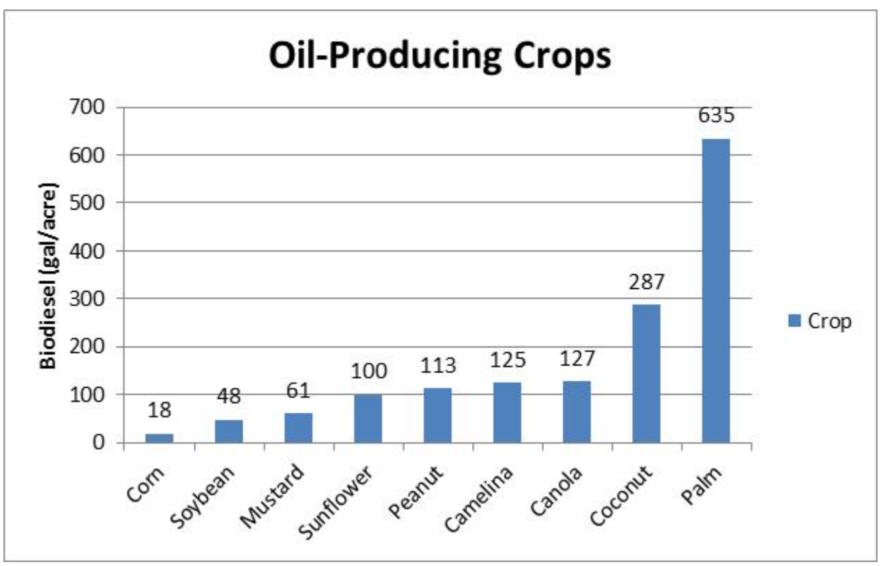


Figure 17. Oil Producing Crops Biodiesel Gallon/Acre Comparison (Tabak, 2009).

Appendices B thru K contain the state agricultural overviews for North Dakota, South Dakota, Montana, Wyoming, Nebraska, Colorado, Kansas, Oklahoma, New Mexico, and Texas respectively.

5.4 Animal Feedstock

Manure is collected on dairy farms where cows are confined, and also on beef feeding sites. A 1,500 pound dairy cow produces about 125 pounds of manure daily (Homan, 2013). Table 3 shows dairy cow populations in the Great Plains states (USDA, 2015).

Table 3. Quantities of Milk Cows in the Great Plains States (USDA, 2015).

State	Number of Dairy Cows
Montana[c]	14,000
North Dakota[a]	16,000
South Dakota[b]	98,000
Wyoming[d]	6,000
Nebraska[e]	54,000
Colorado[f]	145,000
Kansas[g]	143,000
Oklahoma[h]	40,000
New Mexico[i]	323,000
Texas[j]	470,000
Total	1,309,000

[a] See Appendix B North Dakota Agriculture Overview (USDA, 2015).
[b] See Appendix C South Dakota Agriculture Overview (USDA, 2015).
[c] See Appendix D Montana Agriculture Overview (USDA, 2015).
[d] See Appendix E Wyoming Agriculture Overview (USDA, 2015).
[e] See Appendix F Nebraska Agriculture Overview (USDA, 2015).
[f] See Appendix G Colorado Agriculture Overview (USDA, 2015).
[g] See Appendix H Kansas Agriculture Overview (USDA, 2015).
[h] See Appendix I Oklahoma Agriculture Overview (USDA, 2015).
[i] See Appendix J New Mexico Agriculture Overview (USDA, 2015).
[j] See Appendix K Texas Agriculture Overview (USDA, 2015).

On average, each cow daily produces the net equivalent output of 40 cubic feet biogas (Horman, 2013). Therefore, the Great Plains could produce over 50Mft3 of biogas daily, equivalent to 100 GWh of electricity.

Anaerobic Digestion (AD) is the process by which organic substrate is decomposed by micro-organisms in the absence of oxygen, i.e., in an enclosed vessel. End products are sludge and a biogas consisting primarily of methane and carbon dioxide (DeBruyn, 2012). Anaerobic digestion is a complex biochemical reaction series in four stages by different microorganisms as shown in Figure 18. The stages are Hydrolysis, Acidogenisis, Acetogenesis and Methanogenesis.

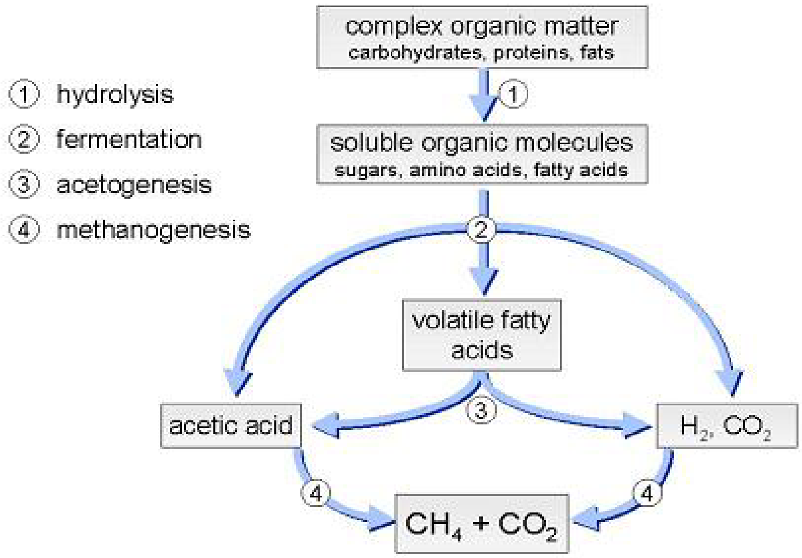


Figure 18. Anaerobic Decomposition Process (Long, N.D.).

Several factors affect the rate of digestion and biogas production, temperature being the most critical. Anaerobic bacteria thrive at temperatures around 98°F, the mesophilic range, and also, 130°F, thermophilic. Decomposition and biogas production occur more rapidly in the latter but the thermophillic process is sensitive to disturbances such as changes in feedstock. Although mesophillic digesters must be larger to provide longer residence time for decomposition, this process is less sensitive to upset or change in operating regimen. With this in mind, mesophillic range digesters will be the focus in this analysis. AgSTAR estimates that there are now 202 anaerobic digester systems operating at commercial livestock farms in the United States. Figure 19 shows the distribution of AD Systems (US EPA, 2013).

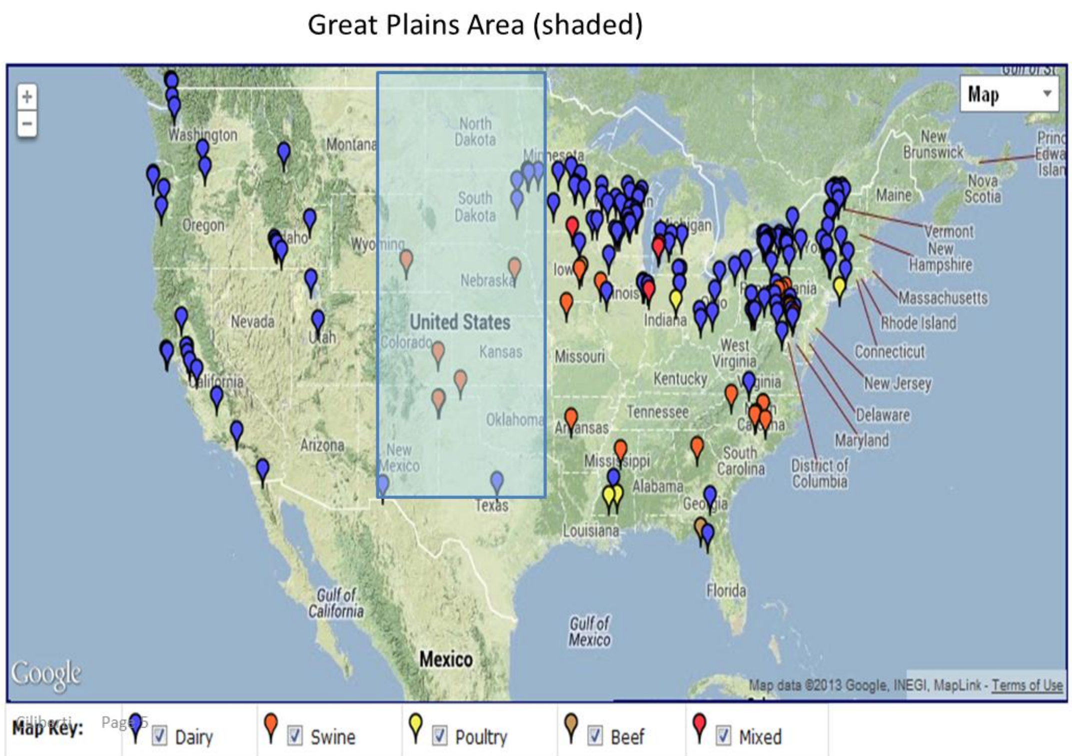


Figure 19. Commercial Livestock Farms with Anaerobic Digesters (AgStar, 2013).

5.5 Algae Feedstock

Microalgae (microscopic algae) include a type of photosynthetic microorganisms that use solar energy and carbon dioxide to produce biomass more efficiently and rapidly than terrestrial plants. Algae is also a feedstock for refining biodiesel. NREL found that high-rate open ponds can produce 30 grams of algae per square meter per day. The 30% lipids content, yielding 4,000 gallons of biodiesel fuel per acre annually, would be the only capital-cost effective approach of using algae as a biodiesel feedstock. NREL also determined that native algae species should be used since they would take over the ponds anyway. Finally, it was determined that the price of biodiesel produced from algal lipids would be in the $2-4 per gallon range (Putt, 2007).

Microalgae growth at economically practical rates (> 20 grams per square meter per day averaged throughout a 300 day growing season) requires more atmospheric carbon dioxide than is naturally available.

The average carbon dioxide content is approximately 350 – 500 ppm by volume. This, however, could be beneficial because algae may mitigate the effects of carbon dioxide from other sources such as power plants.

Algae growth is best developed in the southeastern region of the U.S. due to the abundance of pond-capable land, fresh water, sunshine, and animal husbandry. Algaculture must be intimately coordinated with animal husbandry due to the complementary natures of the plant and animal kingdoms with respect to nutrient needs and waste products. However, significant engineering would be required in the areas of nutrient feeds (notably carbon, nitrogen, and phosphorus) to the ponds, pond design, and the harvesting process (Putt, 2007).

Algae can yield 10,000–15,000 gallons of oil per acre, more than conventionally farmed oil seed crops (Kram, 2008). Extracting the oil from algae is similar to other feedstock processes such as pressing and trans-esterification. Figure 20 shows the locations of algae-related companies, research institutions, national laboratories, demonstration and commercial projects and other efforts undertaken by the Algae Biomass Organization (ABO) members and nonmembers alike. (Algae Biomass Organization, 2013).

Figure 20. Algae Related Establishments (ABO, 2013).

5.6 Woody Biomass

Woody biomass feedstock includes trees (core wood), forest residues, mill residues and construction wood waste. The average energy content of wood depends on the species and mixture of woods used. Figure 21 shows feedstock data from a recent Lockheed Martin project with the following characteristics:

- *Hard/Soft Wood Mix:* Typically 60-65% will be hard wood, with the balance being soft wood, although this can vary significantly (up to 50%).
- *Species* will primarily be white spruce, balsam fir and red maple, although other species (noted below) will also be included in deliveries.
- *Moisture content* is typically between 35-50% (average 46%).
- *Energy content* is 8611 Btu/lb

Species	Hard or Soft Wood	PHYLLIS Ref No**	HHV (dry) kJ/kg	LHV (dry) kJ/kg	Design Assumptions***		
Red Maple*	Hard	2401	n/a	n/a	Ultimate (wt%, dry)	C	52.2
White / Yellow Birch	Hard	74	20120	18702		H	5.95
Sugar Maple / Hard Maple	Hard	n/a	n/a	n/a		O	37.9
Aspen	Hard	n/a	n/a	n/a		N	0.3
Ash	Hard	225	n/a	17815		S	0.4
Hard Wood Chips, Mixed	Hard	250	19268	19448		Ash	3.6
White Spruce*	Soft	161	20469	19160			
Balsam Fir*	Soft	2394	n/a	n/a			
Eastern Hemlock	Soft	n/a	n/a	n/a			
Tamarac Larch	Soft	264	20112	n/a	Energy Density (dry)	HHV (kJ/kg)	20029
White Pine	Soft	304	20700	20721			
Red / Black Spruce	Soft	161	20469	19160		HHV (BTU/lb)	8611
Soft Wood, mixed	Soft	301	18645	19241			

* most plentiful species

**PHYLLIS website: http://www.ecn.nl/phyllis/single.html

*** Mix of hardwood and softwood

Figure 21. Woody Biomass Feedstock Species and Design Assumptions (Lockheed Martin, 2013).

Table 4 shows estimated annual cumulative forest residue quantities (Walsh, 2000).

Table 4. Great Plains Estimated Annual Cumulative Forest Residue Quantities (Dry Tons) by Delivered Price and State (Walsh, 2000).

State	<$30/dry ton delivered	<$40/dry ton delivered	<$50/dry ton delivered
North Dakota	11,000	17,000	21,700
South Dakota	33,000	49,000	64,300
Montana[c]	676,000	1,007,000	1,316,700
Wyoming[d]	132,000	196,000	256,100
Nebraska[e]	19,000	27,000	34,400
Colorado[f]	373,000	554,000	720,300
Kansas[g]	47,000	68,000	88,100
Oklahoma[h]	156,000	228,000	292,200
New Mexico[i]	557,000	814,000	1,050,700
Texas[j]	245,500	Forage	5,069,579

The principal categories of woody biomass conversion technologies for power and heat production are direct-fired and gasification systems. Specific technologies in the direct fire category include stoker boilers, fluidized bed boilers, and co-firing. The gasification category includes fixed bed gasifiers and fluidized bed gasifiers.

Most existing biomass power plants are direct-fired systems. The fuel is burned in a boiler to produce high-pressure steam that is used to supply a steam turbine-driven power generator. In many applications, steam is extracted from the turbine at medium pressures and temperatures. It is then used for process heat, space heating, or space cooling. Co-firing involves substituting biomass for a portion of the main fuel in an existing power plant boiler, such as coal. It is the most economic near-term option for introducing new biomass power generation. Because much existing equipment can be used to charge with biomass without major modifications, co-firing is less expensive than building a new biomass power plant. Compared to the coal it replaces, biomass reduces SO2, NOX, CO2, and other air emissions (U.S. EPA, 2007).

Biomass gasification involves heating solid biomass in an oxygen-starved environment to produce a fuel, a low or medium calorific gas generally called syngas or biogas. Depending on the carbon and hydrogen content of the biomass and the gasifier's properties, the heating value of the syngas, can range from 100 to 500 Btu/cubic foot, which is 10% to 50% that of natural gas. Syngas heating value generally comes from the CO and hydrogen produced by the gasification process. The remaining constituents are primarily CO2 and other incombustible gases. Biomass gasification offers certain advantages over directly burning the biomass because the gas can be cleaned and filtered to remove problem chemical compounds before its combustion.

Most gasification processes include several steps. The primary conversion process, pyrolysis, is the thermal decomposition of solid biomass in an oxygen-starved environment to produce gases, liquids (tar), and char. Pyrolysis releases the volatile components of the biomass feed at around 1,100° F through a series of complex reactions. Biomass fuels are an ideal choice for pyrolysis because they have so many volatile components (70 to 85 percent on dry basis, compared to 30 percent for coal). Further gasification processes convert the leftover tars and char into CO using steam and/or partial combustion. In coal gasification, pure oxygen or oxygen-enriched air is preferred as the oxidant because the resulting syngas has a higher heating value, and the process is more efficient. In biomass gasification, oxygen is generally not used because biomass ash has a lower melting point than coal ash, and also because the scale of the plants is generally smaller (U.S. EPA, 2007).

Transportation costs often account for the majority of the cost of any fuel at the point of use. Thus, to be economically feasible, wood-fired power plants are generally located within 50 miles of the wood source (Combs, N.D). The three Great Plains States with the highest wood residue content are Montana, Texas and Colorado.

5.7 Feasibility Analysis Results

Based on the data analyzed developing the great plains natural resources feasibility study, a conclusion was reached that wind and dairy cow manure are prevalent, sustainable and of great supply but can be distant from urban markets and distributed at low intensity. North Dakota was chosen as the focal point of the study due to the population density being intermittent, dispersed and remote. The combination of population demographics and feedstock resources resulted in North Dakota, South Dakota, and Minnesota region being chosen as the focal point for this new venture.

CHAPTER 6: RURAL ELECTRIFICATION ASSOCIATIONS FEASIBILITY STUDY

The second feasibility study focuses on the potential customers of the integrated renewable energy idea. Rural Electrification Associations (REAs) are ideal candidates since they can provide rural residential and industrial/agricultural power while also providing process fuels for local and export sales, increasing the reliability and independence of the REAs.

6.1 History of REAs

Historically, as late as the mid-1930s, nine out of 10 rural homes were without electric service (NRECA, 2014). Private utility companies, who supplied electric power to most of the nation's consumers, argued that it was too expensive to string electric lines to isolated rural farmsteads (New Deal, 2015)

The Roosevelt Administration believed that if private enterprise could not supply electric power to the people, then it was the duty of the government to do so (New Deal, 2015). On May 11, 1935, Roosevelt signed Executive Order No. 7037 establishing the Rural Electrification Administration (REA) to construct transmission lines to serve “farms and small villages that are not otherwise supplied with electricity at reasonable rates.” The REA was established as an agency of the U.S. Dept. of Agriculture and charged with administering loan programs for electrification and telephone service in rural areas. To implement those goals the administration made long-term, self-liquidating loans to state and local governments, to farmers' cooperatives, and to nonprofit organizations; no loans were made directly to consumers (NRECA, 2014).

In 1935, Bartlett Electric Cooperative in Central Texas was first in the nation to turn on the lights for its members (Bartlett Electric Cooperatives, 2015). By 1940, rural households with electricity had risen over 25 percent and the REA helped to establish 567 cooperatives across the nation providing electricity to 1.5 million consumers in 46 states. By the early 1970s about 98% of all farms in the United States had electric service, a demonstration of REA's success. The administration was abolished in 1994 and its functions assumed by the Rural Utilities Service (Columbia Encyclopedia, 2014). Today, nearly 900 electric co-ops serve 40 million people in 47 states.

Electric Cooperatives are private, independent, non-profit electric utilities that are owned by the customers they serve. They are incorporated under the laws of the states in which they operate and established to provide at-cost electric service. Distribution cooperatives are the foundation of the rural electric network. They deliver electricity to retail customers. Table 5 is a list of all the distribution cooperatives in North Dakota (NRECA, 2015). Generation & transmission cooperatives (G&Ts) provide wholesale power to distribution co-ops through their own generation or by purchasing power on behalf of the distribution members (NRECA, 2014). Although there are fifteen distribution electrical cooperatives in North Dakota, there are only four G&T cooperatives - Upper Missouri, Basin Electric, Central Power and Minnkota Power. However, Upper Missouri Cooperative is not located within the state of North Dakota.

Table 5. North Dakota Electrical Cooperatives (NRECA, 2015).

Distribution Electrical Cooperative	North Dakota Headquarter Location	Generation & Transmission Supplier(s)
Burke-Divide	Columbus	Upper Missouri and Basin Electric
Mountrail-Williams	Williston	Upper Missouri and Basin Electric
McKenzie	Walford City	Upper Missouri and Basin Electric
Roughrider	Dickinson	Upper Missouri and Basin Electric
Slope	New England	Upper Missouri and Basin Electric
Verendrye	Velva	Central Power and Basin Electric
McLean	Garrison	Central Power and Basin Electric
Mor-Gran-Sou	Flasher	Basin Electric
North Central	Bottineau	Central Power and Basin Electric
KEM	Linton	Basin Electric
Cavalier REC	Langdon	Minnkota Power
Northern Plains	Cando	Central Power and Basin Electric
Nodak	Grand Forks	Minnkota Power
Cass County	Kindred	Minnkota Power
Dakota Valley	Milnor	Central Power and Basin Electric

Since only three G&T suppliers within North Dakota are providing all of the state's power and transmission, power contributors local to the distribution cooperatives could provide significant cost savings to customers and increase reliability. However, an impediment to any potential new suppliers is the electricity grid.

6.2 The Grid

The North American electricity grid is the world's largest and most complex power generation, transmission, and distribution system. It delivers electricity to almost all people in the U.S., Canada and a portion of Mexico. This market demands about 830 GW (830,000 MW). The North American grid has about 211,000 miles of high-voltage transmission lines 230 kV and greater, and total assets of more than $1 trillion (Pennsylvania Public Utility Commission, 2011). The system truly is a grid. Transmission lines run not only from power plants to load centers but also from one line to another, providing a redundant system that helps ensure smooth flow of power. Figure 22 illustrates the United States transmission grid.

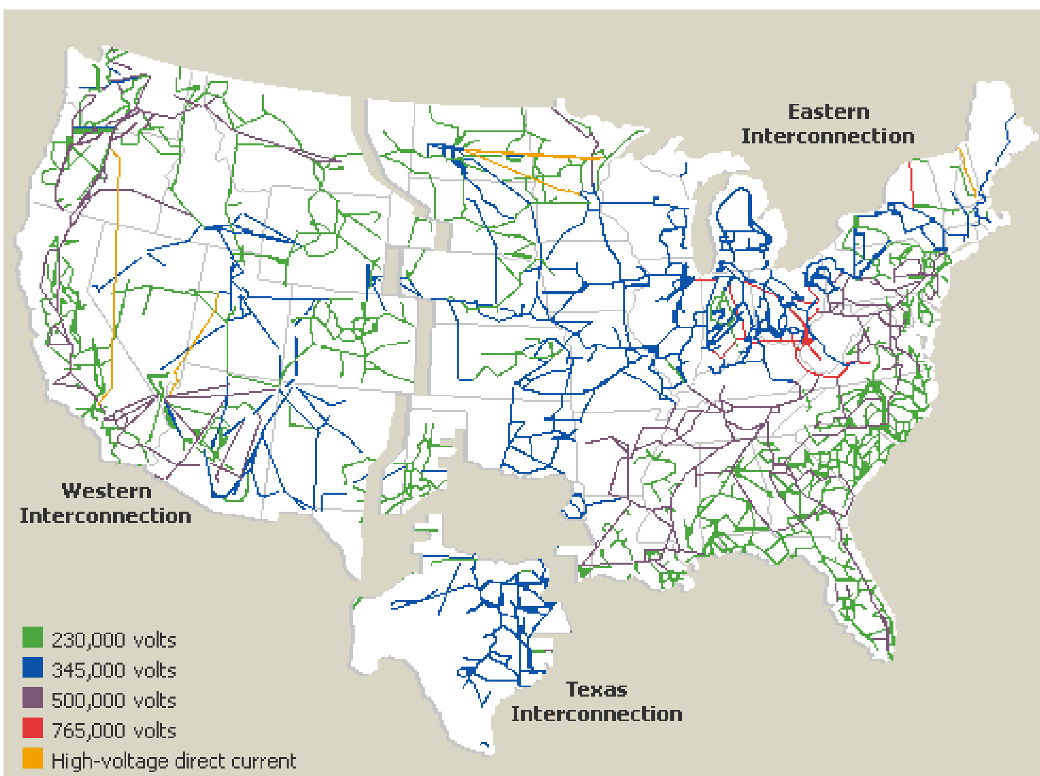


Figure 22. United States Transmission Grid (Global Energy Network Institute, 2014).

If a transmission line is out of service in one part of the grid, power can usually be rerouted through other lines to continue serving customers. While the North American transmission system is commonly referred to as "the grid," there are actually three distinct power networks as shown on Figure 23. Eastern Interconnection covers the eastern two-thirds of the United States, and Canada from Saskatchewan East to the Maritime Provinces. The Western Interconnection includes the western third of the continental United States (excluding Alaska), Alberta and British Columbia in Canada, and a portion of Baja California Norte, Mexico. The third interconnection covers most of Texas.

The Eastern and Western Interconnects have limited ties to each other, and the Texas Interconnect is only linked to the others via direct current lines. Both the Western and Texas Interconnects are linked with Mexico, and the Eastern and Western are strongly tied with Canada. All electric utilities in the mainland United States are tied to at least one other utility via these power grids (Energy Library, 2009). However, the Great Plains is divided between all three Interconnects, which creates additional challenges in power integration, variations, distribution and reliability logistics, when exporting power to the rest of the country as shown in Figure 24.

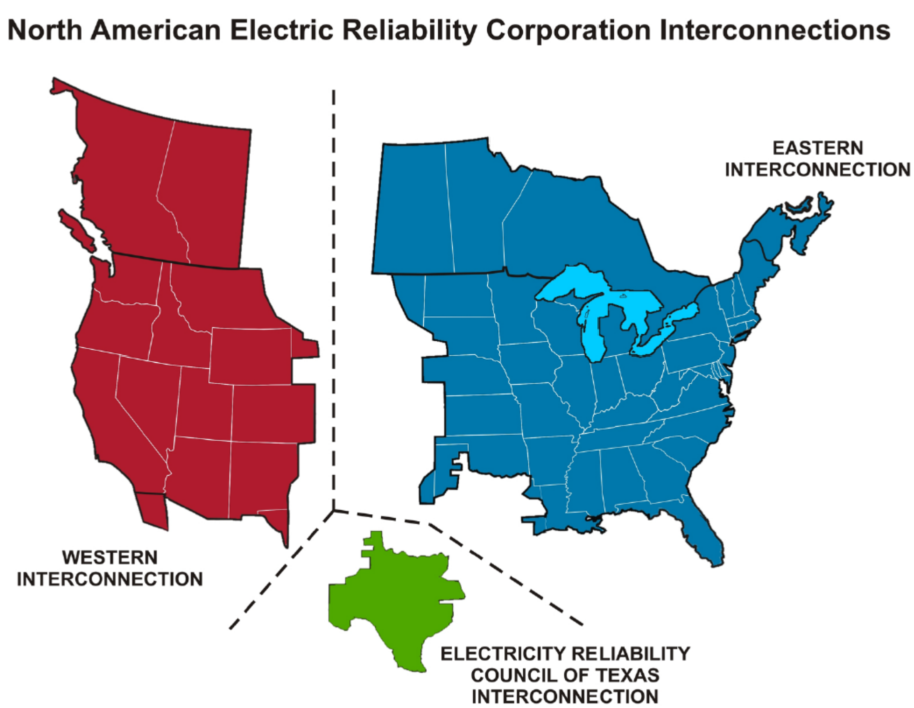


Figure 23. North American Grid Interconnections (US DOE, 2013).

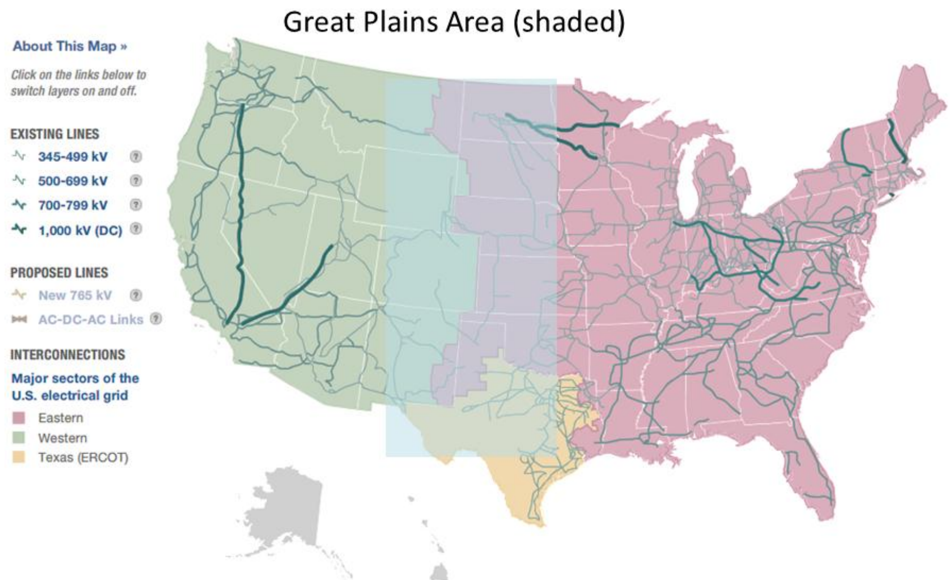


Figure 24. Existing Transmission Lines in Great Plains (Shaded) of the United States (Prince, 2009).

The transmission system was built over the past 100 years. The model vertically integrated utilities that produced electricity at large generation stations either close to fuel supplies or to transportation infrastructure, and then relied on transmission facilities to move electricity to their customers. Interconnections among neighboring utility systems were installed to increase reliability and share excess generation during certain times of the year.

Transmission congestion or bottlenecks result when or where there is insufficient capability to accommodate all requests to ship power over the lines and maintain adequate safety margins for reliability. Because electricity cannot yet be stored economically, system operators may deny requests for service in order to prevent lines from becoming overloaded. New transmission facilities would alleviate these stresses. However, the North American Electric Reliability Council (NERC) reports that investment in transmission facilities is lagging far behind both investment in new generation and growth in electricity demand. Construction of high voltage transmission facilities is expected to increase by only 6 percent (in line-miles) during the next 10 years, in contrast to the expected 20 percent increase in electricity demand and generation capacity (in MW) (US DOE, 2002).

Although it is not expected that transmission capacity would grow as quickly as new generation capacity or demand, even this projected growth is not adequate to ensure reliability and sustain continued growth of competitive regional wholesale electricity markets (Abraham, 2002). "Everyone pretty much agrees that the current transmission system is not built to do this job," says Jon Wellinghoff, chairman of the Federal Energy Regulatory Commission (FERC). It is antiquated and inefficient, as shown by 9% of all power generated being lost in transmission, compared with 3.5% typical in other countries. Also, mandates for renewable energy in most states and proposed carbon-emissions curbs require that the system get greener and cleaner. As a result, billions of dollars of transmission upgrades must be made as shown in Figure 25 (Carey, 2009). As shown, a significant amount of these upgrades are required in the Great Plains region.

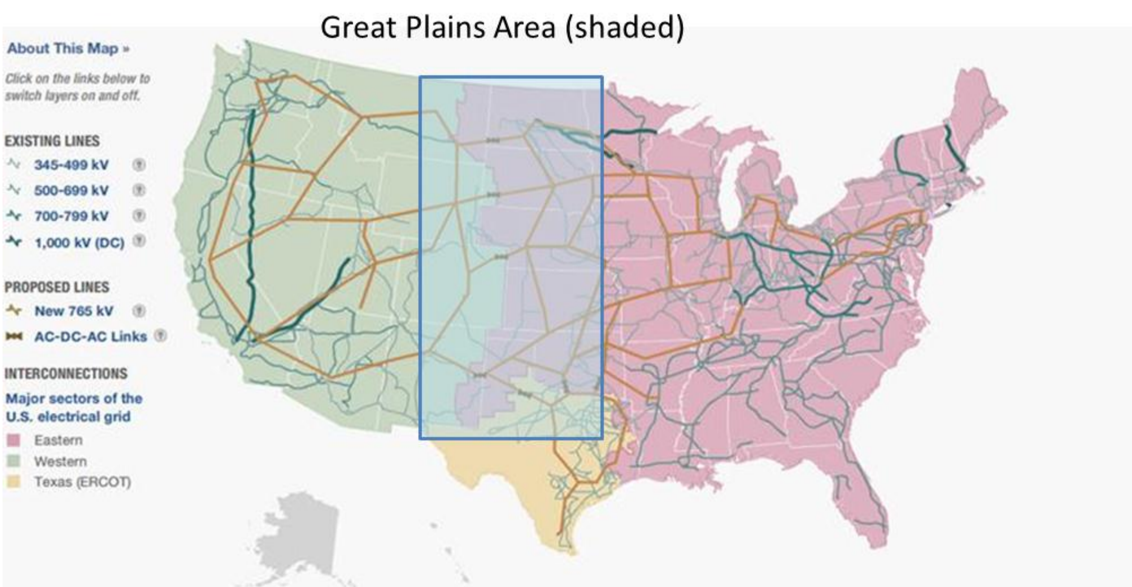


Figure 25. Proposed Upgrades to the North American Electric Grid (Prince, 2009).

The over-burdened Grid precludes the addition of a sufficient quantity of electricity generated from wind farms in the Great Plains that could supply power to the east and west coasts and replace existing fossil-fuel power plants. This is due to the fact that the Grid was developed such that the high-capacity transmission lines are located in areas of dense population as shown in Figure 24 and is the exact opposite of where current wind and biofuel feedstock resources are the most robust. Significant investments in the Grid infrastructure would be required to integrate Great Plains generated renewable power. Transmission costs and losses favor consumption of power nearer to points of generation (Caplinger, 2012).

6.3 Feasibility Analysis Results

Based on the Rural Electrification Associations feasibility study, it is clear that distribution REAs are ideal candidate customers of an energy solution that would allow them to produce and provide power independently from the generation and transmission REAs they currently rely upon. In addition, an optimal renewable energy solution cannot afflict the grid due to the grid’s inability to sustain continued growth and ongoing over-burdening issues.

CHAPTER 7: LIFE CYCLE ASSESSMENT AND PROJECT ECONOMICS FEASIBILITY STUDY[1]

Feed-in tariffs and Renewable Portfolio Standards (RPS) are among the most prominent policies to address anthropogenic influence on climate change. Implementation of RPS favorably affects renewable energy supply and rural development while reducing the land available for meeting demand for food and feed resulting from global population growth. Even in the vast Great Plains of the United States, land requirements are primary considerations between increasing renewable energy capacity and food and feed production.

This feasibility study applies life cycle assessment (LCA) and project economics to estimate and compare the land intensity and profitability of anaerobic digestion and wind energy projects in the Great Plains. The results show that significantly more energy and revenue can be generated per hectare of land using wind versus anaerobic digestion. Economically, the benefit-to-cost ratios of wind farms were almost twice as favorable as anaerobic digester facilities. Wind farms have consistent benefit-to-cost ratios of 2.15 while the anaerobic digester facilities benefit to cost ratios range from 1.2 to 1.25.

Legislature changes to RPS could incentivize increasing the number of anaerobic digesters while also assisting in reversing the current trend of diminishing dairy farms while reducing climate change risks and creating new economic opportunities for renewable energy.

7.1 Introduction

The economic feasibility of energy choices, energy security challenges and environmental impacts of operations such as those caused by climate change are among the most significant factors considered in energy policy decisions today. Since the 1990s, there has been significant growth in the number of renewable energy policies implemented to address these concerns, including quantity forcing and cost reduction (Beck and Martinot 2004). Specifically, feed-in tariffs and Renewable Portfolio Standards (RPS) are among the most effective policies for reducing greenhouse gas emissions through using a regulatory mandate to increase the production of energy from renewable sources and remain the most commonly used support mechanisms.

[1]*A Life Cycle Perspective on Land Use and Project Economics of Electricity from Wind and Anaerobic Digestion* by Carlo Ciliberti et. al. Energy Policy Volume 89 February, 2016, Pages 52-63.

Feed-in tariffs have been enacted in 108 jurisdictions at the national or state/provincial level around the world. RPS policies are most popular at the state and provincial levels as they are in place in 26 countries (United States, China, Japan, Canada, Germany, etc.) at the national level and in 72 states/provinces (REN21, 2015). While beneficial for reducing climate change impacts, renewable technologies also contribute to land use challenges. As the number of RPS initiatives that affect electricity supply companies increases, land use for renewable energy projects is expected to become more competitive with the steady growing demand for food and feed resulting from global population growth (Valentine et. al., 2012). Ethical debates over land use may intensify as population growth, land availability and renewable energy projects all compete against rising food prices and population growth (Harvey et. al, 2011). Based on population growth projections, it is predicted that by 2030, the world will need to produce 50% more food, 50% more energy and 30% more fresh water (Alexandros et. al., 2006). About half of global usable land is already in pastoral or intensive agriculture. By 2050, the global population is projected to be 50% larger than today's population and international grain demand is projected to double (Tilman et. al., 2002). With this expected population growth and development pressures, land-use change will continue as food demand rises and urban areas expand in many parts of the world (DeFries et. al., 2004). The availability and use of land will be one of the primary considerations in the majority of future energy projects, particularly for renewable energy, which is considered to have significant spatial requirements as also analyzed by Kimming et. al. (2011), Canals et. al. (2007), Loiseau et. al. (2013), and Fthenakis et. al (2009).

There is tremendous potential for harnessing different forms of renewable energy that could add significantly to energy supply diversity in coming years. Within the United States alone, twenty-nine states and Washington, D.C. now have RPS (US DOE, 2015). As renewable energy competes financially with fossil fuels, these standards ensure that the public benefits of renewable energy continue to be realized as electricity markets become more competitive. This form of policy instrument incents companies that sell electricity to retail customers to support renewable energy generation. The standards range from modest to ambitious and qualifying energy technologies vary. For example, Hawaii is targeting 40% of energy generated to be from renewable resources by 2030; California is targeting 50% by 2030 (Richardson, 2015) but both North Dakota and South Dakota are only targeting 10% by 2015 (Leon, 2013).

With increasing renewable capacity being deployed due to feed-in tariffs and RPS (Edwards et. al., 2015), there is a need to better understand the competing land requirements of and economic challenges for different energy technologies. To address this, we analyze the land use requirements and project economics for both wind and biofuel renewable energy production through anaerobic digestion (AD) of dairy cow wastes for several of the Great Plains states of the United States. These two sources were chosen since they are prevalent resources available in the Great Plains and offer less competition to agricultural land assets than other renewable energy technologies such as photovoltaic or biomass projects.

The Great Plains of the United States have been assessed as having enough wind to power the entire country (Wishart, 2011). In fact, North Dakota alone has wind resources that, if harnessed, could provide more capacity than all the combined fossil-fueled power plants in the United States (NRDC, 2014). In addition to wind, the land available in the Plains states are an excellent biomass resource for biofuel feedstock such as native grasses, corn stover, wheat straw, and organic and inorganic wastes due to the natural climate and abundant rainfall. However, simultaneously meeting the rising demand for food and feed from global population growth along with increased demand for agriculturally based biofuels will require expanding agricultural production. Industrialized nations, such as the United States, are unlikely to have the land base needed to meet their growing demand for agriculture-based biofuels and other forms of renewable energy concurrent with existing and future multiple use of landscapes (Gibbs et. al., 2008). Due to having a relatively low population density, and abundant wind and anaerobic feedstock resources, the North Dakota, South Dakota and Minnesota region was chosen as the focal point for this analysis.

There have been numerous assessments of the land footprint of wind energy; however, there has been little completed on AD facilities. Existing assessments of wind farms such as the National Renewable Energy Laboratory (NREL) includes total land area but contain very limited published data on permanently disturbed land in North Dakota (Denholm, 2009). Permanently disturbed land includes land alterations such as access or service roads, foundations, pads, Operations and Maintenance Facilities, etc. that make the land unusable for other services or activities such as farming or animal grazing. Additional studies of wind farms such as Martinez et al (2009) analyze the life cycle of a wind turbine's key components including the foundation but do not include each wind turbine's access road in the analysis.

While several broad comparisons of the land use of energy include wind, AD has yet to be explored in depth. Other studies such as that by Fthenakis and Kim (2009) compared land requirements of different types of renewable energy to conventional sources but the analysis did not include anaerobic digestion. Pimentel et al. (2002) focus on the quantity of biogas produced by anaerobic digestion; Berglund and Borjesson (2005) discuss material and energy flows of anaerobic digestion and biogas production; Cherubini et. al (2009) analyze biofuel and bioenergy systems not specific to anaerobic digestion concentrating on greenhouse gases; Porschl et. al. (2010) analyze biogas production and energy efficiency but the authors did not analyze land use. Anaerobic digester project studies through the AgSTAR program list the operational anaerobic digester projects that have received government subsidies (US EPA, 2013). This information focuses on installed capacities, baseline systems and methane emission reductions but not land use requirements. The information presented in this report advances the current state of data by analyzing and comparing AD to wind projects with respect to land use.

During the implementation of feed-in tariffs and RPS, there is an opportunity to develop a variety of renewable energy technologies. While there are clear greenhouse gas (GHG) reduction benefits, there is a need to better understand the unintended impacts or consequences of factors that inhibit meeting multiple sustainability targets so that they can be mitigated. When food and energy projects compete for land, the commodity prices of products derived from land increase, which in turn may affect productivity, availability of land, and a greater contribution to GHG emissions, creating a potentially vicious circle (Harvey, 2010). This paper aims to address the research gap on land disturbance of both anaerobic digester and wind farm projects and to develop an approach for assessing land and economic impacts that can be applied across regions where wind and anaerobic digestion opportunities exist. A specific case study of the upper Midwest, United States is examined to develop this approach where both of these technologies are promising options for meeting RPS commitments. North Dakota has several established wind farms while South Dakota and Minnesota are home to established anaerobic digesters. The focus of this analysis will be on North Dakota, South Dakota and Minnesota with a life cycle inventory of land use associated with each type of project. We compare the results between the land use requirements of AD and wind energy projects which will then be used to identify an integrated renewable energy solution for the Great Plains. Globally, such an approach can provide additional decision support in the development of renewable energy policy where anaerobic digestion and wind energy resources are concurrently available.

7.2 Life Cycle Assessment

LCA (ISO 14040: 2006) is a decision making tool used to identify environmental burdens and evaluate the environmental consequences of a product, process or service over its life cycle (i.e. from extraction of resources through to the disposal of unwanted residuals). However, the assessment of impacts caused by the use of land for production purposes has not been comprehensively addressed throughout the development and standardization process of LCA methodology (Gagnon, et. al (2002) and Cherubini et. al (2011)). LCA was designed largely for products manufactured in industry, directed particularly at the assessment of intensive industrial production processes that take place on rather small areas of land. Hence, land use was not identified early as an important form of impact on the environment (Doka et. al, 2002). In contrast to industrial products, the production of renewable energy does not take place in a factory but can occupy large tracts of land, depending on technology and feedstock (Fthenakis, 2009). Far more than for other energy products, an understanding of the impacts on land is essential for the full assessment of renewable energy projects due to the broad assumption that all renewable energy consumes vast amounts of land (Pimentel et. al, 2002). One of the key challenges for the evaluation of land impacts in LCA is the challenge of quantifying the values society ascribes to land. Since LCA methods do not offer a standardized approach to inventorying and evaluating land use, the development of supplemental methods is needed for the full quantification and assessment of environmental impacts.

To ensure a manageable scope and to understand the end use impacts of AD and wind electricity, we refine the assessment of land value to economic rather than broader indicators such as biodiversity. An economic assessment was performed to determine the financial differences between land uses. Land economic value was calculated based on average installed costs amortized over the typical plant life span of 30 years as well as annual operations and maintenance costs. While we do not include non-monetary costs, this provides a basis for how values may be included within LCA, provided the values can be monetized.

7.3 Land Use Requirements

The development of a wind power plant or a dairy farm AD facility results in a variety of temporary and permanent land disturbances. Permanent disturbances include land occupied by foundations, crane pads, access roads, substations, service buildings, and other infrastructure which physically occupy land area, or create impermeable surfaces. While land cleared around a turbine pad does not result in impervious surfaces, this modification represents a potentially significant degradation in ecosystem quality. In addition to permanent impacts, which last the life of the facility, there are temporary impacts from plant construction. These impacts are associated with temporary construction storage, access and lay-down areas. After plant construction is complete, the temporary disturbed land areas eventually return to their previous state. The amount of time required to return to its “pre-disturbance condition” varies considerably; for example, it is estimated at two to three years for most grasslands and “decades” in desert environments (Denholm et. al, 2009). For this analysis, only permanent land disturbances are considered.

7.3 Methods

A life cycle assessment (LCA) framework following ISO (2006) standards is used to inventory the land disturbance for wind and AD electricity production. To develop a more comprehensive approach to land use assessments of wind farms and anaerobic digesters in the Plains states, permanent land disturbances were measured and recorded based on satellite views of each facility (described in the Analysis section). The electric energy delivered to market (MWh) is the product of the power production capacity, the nameplate capacity factor, and time. We estimate land intensity as the ratio between total land disturbed and electrical energy produced in one hour (ha/MWh) in equation 6 in the Analysis section. All fifteen major wind farms throughout North Dakota are considered in this analysis. Currently there are no AD systems operating at commercial livestock farms in North Dakota. Therefore, we consider four of the closest AD systems to North

Dakota, which produce electricity in South Dakota and Minnesota. Figure 26 shows the locations of the analyzed wind farms and anaerobic digester projects.

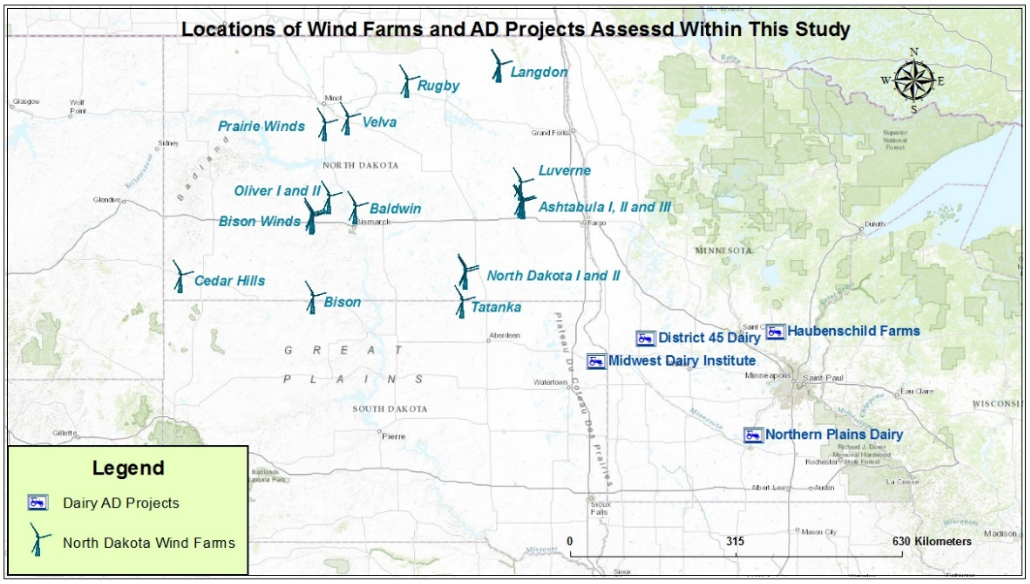


Figure 26. Locations of Wind Farms and AD Projects Assessed within this Study. Wind Locations are from the US Geological Survey (USGS, 2014) and AD Locations from AgStar (EPA, 2014).

The functional unit used in the life cycle assessment is 1 megawatt (MW) of power and 1 megawatt-hour (MWh) of electricity generated. The metric used to compare the land use requirements between wind energy and dairy farm waste anaerobic digestion is the hectare.

The life cycle process flow diagram for AD (Figure 27) and wind (Figure 28) outline the system boundary and identify land inputs for raw material extraction, manufacturing of equipment, transportation, facility construction, operation and maintenance, transmission and distribution, and end of plant life.

The LCA system boundary focuses only on project construction, operation and maintenance processes and activities involved in the land inventory analysis. These aspects represent the Technological Whole System (TWS) as a method used for the portion of the LCA that is central to the investigation (Tillman, 1993).

In addition, transmission lines and utility pole land disturbances are purposely excluded from the system boundaries since available data are very inconsistent and sparse, indicating a need for a robust assessment which is out of the scope of this study. Many of the wind turbine transmission cables are either underground or documentation on the overhead lines is unavailable. For example, of the fifteen major wind farms in North Dakota, only eleven of the substations could be identified while most of the transmission lines could not be verified to be above-ground or below-ground cables as shown in Table 6.

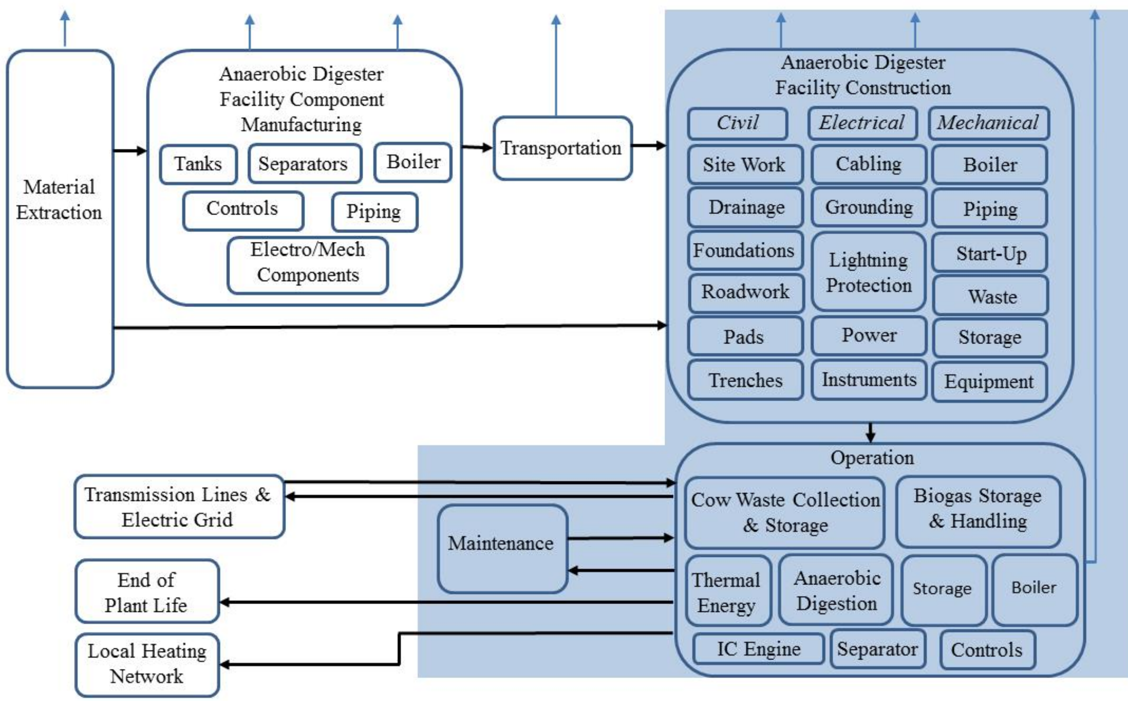


Figure 27. AD Life Cycle Process Flow Diagram. The Shaded Area Represents the System Boundary Considered in this Study.

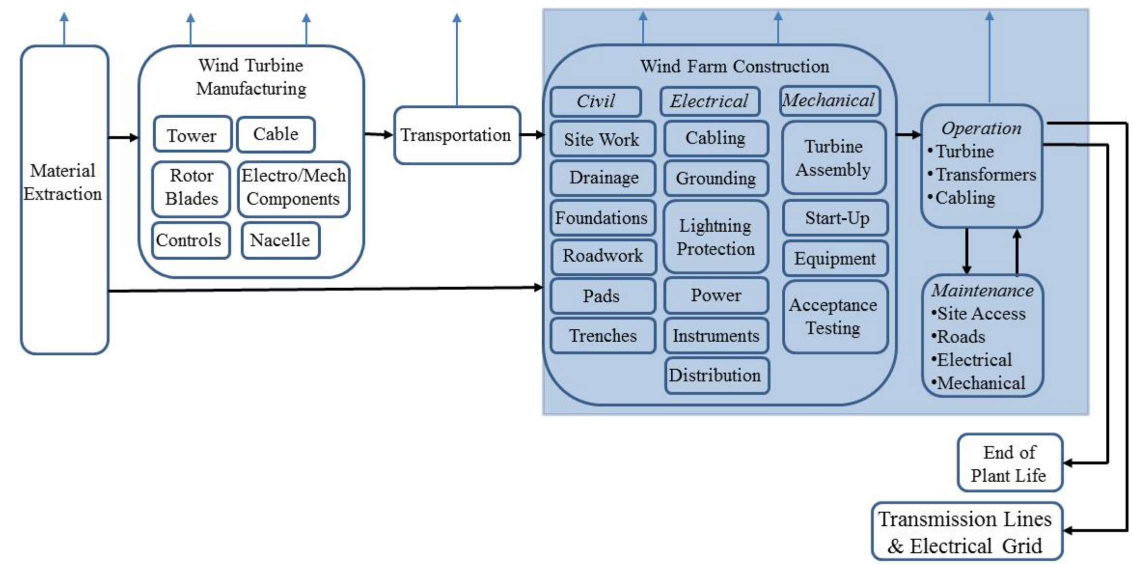


Figure 28. Wind Farm Life Cycle Process Flow Diagram. The Shaded Area Represents the System Boundary Considered in this Study.

Table 6. North Dakota Wind Farm Transmission/Distribution Data.

Wind Farm	**Turbine (Qty)**	**Capacity (MW)**	**Transmission Voltage (kV)**	**Substation Identified**	**Transmission Details[a]**
Ashtabula I	131	196.5	230	Identified	9.5 mile line connect Pillsbury substation
Ashtabula II	80	120.0	230	Identified	9.5 mile line connected to Pillsbury substation
Ashtabula III	39	62.5	230	Identified	9.5 mile line connected to Pillsbury substation
Baldwin	66	102.4	34.5	ND	Unknown
Bison	101	292.0	230	Identified	465 mile DC line from Square Butte substation to Arrowhead substation
Cedar Hills	13	19.5	57	Identified	Connecting Bowman, ND to Baker, MT
Langdon Wind	133	199.5	115	Identified	35 mile Langdon to Hensel
Luverne North Field	33	49.5	230	Identified	Underground connection lines and above ground transmission line combination
Oliver I	22	50.6	ND	ND	Underground collection cables

Oliver II	32	48.6	ND	ND	Underground collection tables
N. Dakota I & II	41	61.5	41.6	Identified	ND
Rugby	71	149.1	230	ND	465 mile DC line from Square Butte substation to Arrowhead substation
Prairie Winds	77	115.5	ND	Identified	ND
Tatanka	61	92.0	230	Identified	55 miles of underground cables and 15 mile transmission line
Velva	18	11.8	ND	Identified	ND

ND = No Data

[a] Transmission data from http://eerscmap.usgs.gov/windfarm/

7.4 Land and Economic Analysis

Determining the permanently disturbed land areas for the wind farms and anaerobic digester facilities involved several steps. For each wind farm, the location and quantity of turbines was found in published data and satellite maps from the U.S. Geological Survey (USGS, 2014) and google maps. Operational anaerobic digester projects within the United States were identified in published data and satellite maps using the Environmental Protection Agency's AgSTAR interactive map (EPA, 2014) and google maps.

Next, the sites were divided into smaller, more manageable areas so that permanently disturbed land could be quantified as illustrated in Figures 29 and 30. Appendix L through Appendix Z show the detail for each North Dakota wind farm.

(a) **(b)** **(c)**

Figure 29. Satellite Images of a Wind Farm. (a) Complete Wind Farms Divided into Manageable Areas. (b) Wind Turbine Foundation and Access Road Width. (c) Access Roads for Area 4.

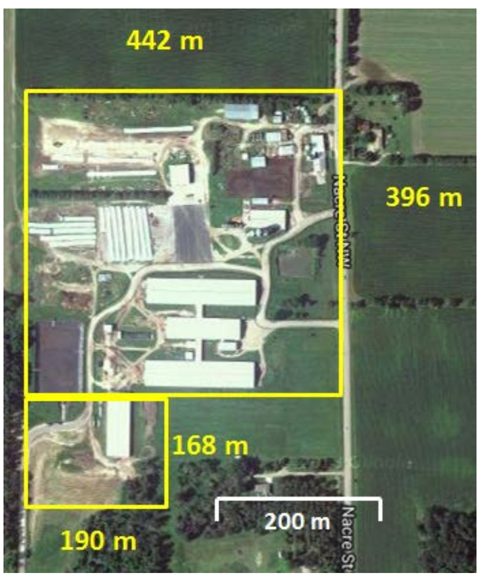


Figure 30. Satellite Image of an Anaerobic Digester Facility with Measurements.

Each area was then measured using the appropriate scale to determine the length and width of access roads and the radius of turbine foundations. The permanently disturbed land area was determined by the following equations:

$$\text{Area}_{TF} = (\pi r^2) \text{ (hectares).} \tag{1}$$

$$\text{Area}_{AR} = (LW) \text{ (hectares)} \tag{2}$$

$$Area_{AD} = (LW) \text{ (hectares)} \tag{3}$$

where TF is the turbine foundation, AR is the access road, r is the radius of the foundation; L is the length of the access road/pad; W is the width of the access road/pad; and AD is the anaerobic digester facility.

Finally, the measurements for all permanently disturbed land areas on each wind farm such as turbine foundations, access roads and substation areas were summed using equation (4).

$$A_{tot} = \sum_{i=1}^{n} Ai \tag{4}$$

where A_{tot} is the total area disturbed and n is the number of wind turbines, access roads, foundation pads, facilities, etc..

The value of the total area disturbed is calculated by multiplying the total disturbed area by the current land market value.

$$LV_{market} = A_{tot} * MV \tag{5}$$

where LV_{market} is the market land value and MV is the market value specific to the North Dakota, South Dakota and Minnesota region of the United States.

The summation of all the permanently disturbed land areas was then used to calculate the new Land Occupation Value in hectares per Megawatt:

$$LOV = \frac{A(tot)}{C(MW)*CF} \tag{6}$$

where LOV is the Land Occupation Value in hectares per Megawatt, C(MW) is the installed capacity in Megawatts and CF is the capacity factor.

The average installed capital cost of each wind farm was determined using the United States Department of Energy data for wind farms between 5 MW and 200 MW. Since the project costs were identified as being between $1893/kW to $2692/kW (US DOE, 2014), the midpoint of $2292.50/kW was used for our calculations, with the extremes tested in the sensitivity analysis as shown in Table 1. For anaerobic digester projects, installed costs range between $1000 and $2000 per cow depending on the size of the herd (AgSTAR, 2013). $1500 per cow was used for this analysis.

$$CC_{AI} = C_{unit} * F_{cap} \tag{7}$$

where CC_{AI} is the average installed capital cost; C_{unit} is the project cost per unit of measure; and F_{cap} is the facility's capacity.

From the average installed capital cost of the wind farm, the annual loan payment was calculated based on a 30 year loan that was obtained for 90% of the installed cost at a 5% interest rate. It was assumed that 10% of the installed cost would be paid as cash. Annual loan payments are based on 12 monthly loan payments.

$$\text{Annual Loan Payment} = 12\left[\frac{\mathrm{Pr}(1+r)^n}{(1+r)^n-1}\right] \tag{8}$$

where P is the amount borrowed, r is the monthly interest rate; and n is the life of the loan in months.

Annual operations and maintenance costs are between \$30 and \$50 per kW for turbines 1 MW or greater in the United States (US DOE, 2014). The average value of \$40 per kW was selected for our annual O&M costs.

$$AC_{Total} = ALP + OM \tag{9}$$

where AC_{Total} is the total annual costs; ALP is the annual loan payment; and OM are the annual operations and maintenance costs.

Annual electricity revenue for wind farms was calculated using the North Dakota electricity price of \$0.0862/kWh (Otter Trail Power Company, 2014). There is also a federal production tax credit for wind energy extended thru 2016 of \$0.023/kWh (DSIRE, 2014).

$$AR_{Total} = AER + APTC \tag{10}$$

where AR_{Total} is the total annual revenue; AER is the annual electricity revenue; and APTC is the annual production tax credit.

A benefit-to-cost ratio was then developed for each wind farm to summarize the value of each project.

The capital cost loan metrics for the anaerobic digester projects were kept the same as the wind farms. The annual loan payment was calculated based on a 30 year loan that was obtained for 90% of the installed cost at a 5% interest rate. For consistency, it is assumed that 10% of the installed cost was paid as cash. Annual loan payments are based on 12 monthly loan payments. Equation 8 was used to calculate the annual loan payment.

Annual dairy farm costs are based on the USDA's Agriculture Resource Management Survey of milk producers and updated using current USDA average production per cow and production input indexes (USDA, 2014). Average annual dairy farm costs in the United States of \$19.2/cwt were used.

$$AC_{AD} = ALP + AFC \tag{11}$$

where AC_{AD} is the total annual costs for the AD facility; ALP is the annual loan payment and AFC is the annual farm costs.

For consistency in comparing wind and AD facilities, the annual electricity revenue for AD facilities was calculated using the North Dakota electricity price of $0.0862/kWh (Otter Trail Power Company, 2014). The state of Minnesota also has a $0.015/kWh electricity generation by anaerobic digestion incentive. However, neither states of North and South Dakota have any such incentive (DSIRE, 2014).

Carbon Credits are verified units of voluntary reduction of atmospheric carbon emissions, usually expressed as Carbon Reduction Tons (CRT's) or Tons of CO_2 Equivalent (CO_2E). AD facilities generate carbon credits by reducing greenhouse gas emissions which can be an additional source of revenue.

Another revenue source for AD facilities is animal bedding, which is a byproduct of the AD digestate. Digestate is the liquid or solid material generated after the anaerobic digestion process. The solids are used "as is" for such uses as animal bedding (Alexander, 2012).

Dairy farms themselves generate revenue from the milk that is produced by the herd population. An average United States dairy cow produces 22,258 pounds of milk annually (USDA, 2014). Since milk is measured in hundred pound weight or cwt, equation 12 is used to calculate the annual milk production.

$$AMP = (22{,}258 Lb/cow * X_{cows})/100 \tag{12}$$

where AMP is the annual milk production in hundred pound weight. Annual Milk Revenue is calculated by multiplying the cwt quantity of milk by the current milk price within the United States of $23.20 (USDA, 2014).

$$AMR = \$23.20/cwt * AMP \tag{13}$$

where AMR is the annual milk revenue.

$$AR_{AD} = AER + ASI_{AD} + CC + AMR + AAB \tag{14}$$

where AR_{AD} is the total annual revenue for AD facilities; AER is the annual electricity revenue; ASI_{AD} is the annual state incentive for AD generated electricity; CC is the carbon credits; AMR is the annual milk revenue; and AAB is the annual animal bedding savings.

A benefit-to-cost ratio was then developed for each AD facility to summarize the value of each project.

A number of the model inputs are subject to uncertainty, annual variability or differences across projects. To examine uncertainty, a sensitivity analysis was performed for each of the factors listed in Table 7 and described in the Results section.

Table 7. Wind Turbine and AD Facility Baseline and Boundary Data.

Sensitivity Factor	**Lower Value**	**Baseline Value**	**Higher Value**
Electricity Price	$0.06/kWh	$0.0862/kWh	$0.10/kWh
Interest Rate	3%	5%	7%
Wind Capital Cost	$1893/kW	$2292.5/kW	$2692/kW
AD Capital Cost	$1K/Cow	$1.5K/Cow	$2K/Cow
Wind O&M Costs	$30/kW	$40/kW	$50/kW
Dairy Milk Revenue	$21/cwt	$23.2/cwt	$25/cwt
Dairy Farm Costs	$18.cwt	$19.2/cwt	$21/cwt
AD Incentive	$0.01/kWh	$0.015/kWh	$0.02/kWh

7.5 Wind Farm Results

All the North Dakota Wind Farms studied had consistently favorable benefit-to-cost ratios of 2.15. Table 8 shows revenues and costs for each North Dakota wind farm.

Table 8. Revenues and Costs for North Dakota Wind Farms.

Facility Name	**Annual Electricity Revenue[a] ($M)**	**Production Tax Credit[b] ($M)**	**Installed Capital Cost[c] ($M)**	**Annual Loan Payment[d] ($M)**	**Annual O&M Costs[e] ($M)**
Bison	$86	$23	$669	$39	$12
Ashtabula I	$58	$15	$450	$26	$8
Langdon	$59	$16	$457	$27	$8
Rugby	$44	$12	$342	$20	$6
Baldwin	$30	$8	$235	$14	$4
Prairie Winds	$34	$9	$265	$15	$5
Ashtabula II	$35	$9	$275	$16	$5
Tatanka	$27	$7	$210	$12	$4
Cedar Hills	$6	$2	$45	$3	$1
Ashtabula III	$18	$5	$143	$8	$3

Luverne	$15	$4	$113	$7	$2
Oliver II	$14	$4	$111	$6	$2
N. Dakota I & II	$18	$5	$141	$8	$2
Oliver I	$15	$4	$116	$7	$2
Velva	$3	$1	$27	$2	$0

Table 8 (continued)

[a] Annual Electricity Revenue is based on the wind farm nameplate capacity multiplied by the North Dakota wind capacity factor of 0.389 (US Energy Information Administration, 2012) for 8760 hours per year at $0.0862 per kWh (Otter Trail Power Company, 2014).
[b] Federal production tax credit for wind energy extended thru 2016 of $0.023/kWh (DSIRE, 2014).
[c] Based on the midpoint project data costs from the US DOE data for wind farms between 5 and 200 MW.
[d] Annual loan payment based on a 30 year loan obtained for 90% of the installed cost at a 5% interest rate.
[e] Annual O&M costs based on the average of $40 per kW for turbines greater than 1 MW (US DOE, 2014).

A sensitivity analysis was performed on the electricity price, loan interest rate, O&M cost and capital cost variables to see which had the greatest impact on the benefit-to-cost ratio. Figure 31 summarizes the sensitivity analysis.

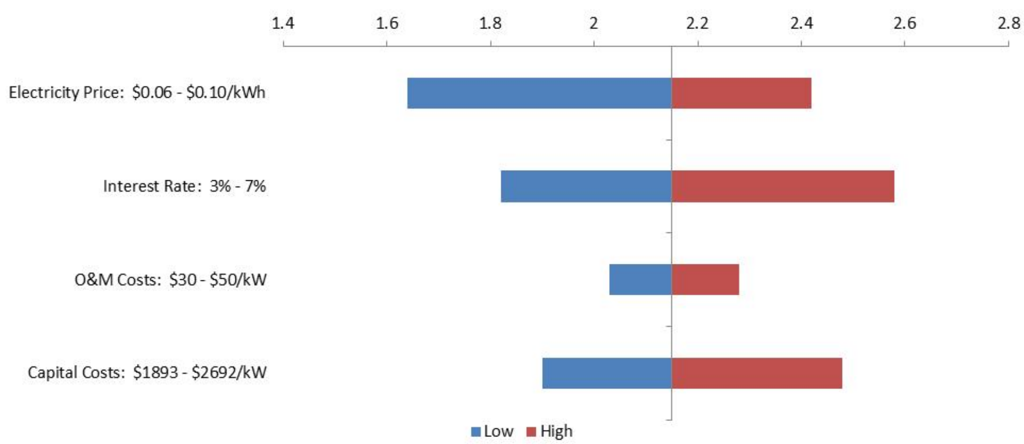


Figure 31. North Dakota Wind Farm Sensitivity Analysis of Benefit-to-Cost Ratio Input Variables.

Analyzing each variable independently, the price of electricity had the greatest impact on the benefit-to-cost ratio range (1.6 to 2.4). A lower loan interest rate had the potential to increase the benefit-to-cost ratio the most at 2.58 with a 3% loan over 30 years. Capital costs per kW also had a significant impact while variations in O&M costs had the least impact.

Using a life cycle framework, North Dakota Wind Farms have a benefit-to-cost ratio of 2.15 and depending on their nameplate capacity, use between 2 and 129 hectares of permanently disturbed land (Figure 32 and Table 9).

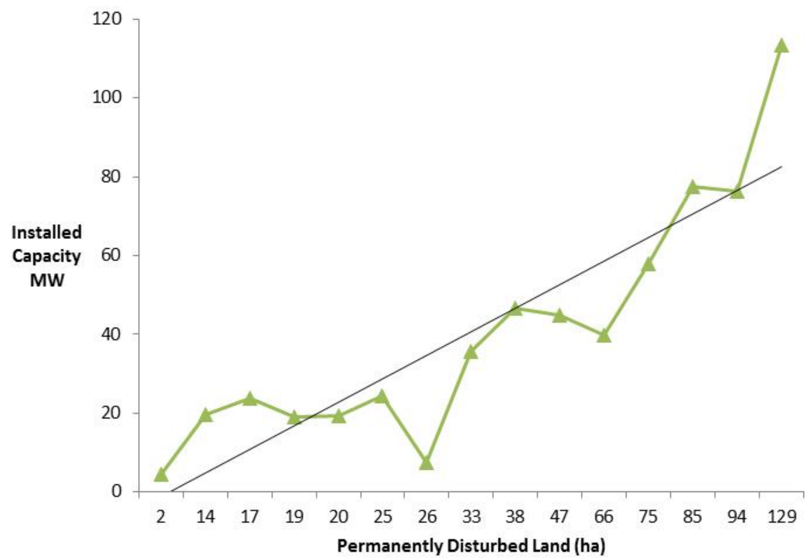


Figure 32. North Dakota Wind Farms Installed Capacity vs. Permanently Disturbed Land.

Table 9. North Dakota Wind Farm Land, Capacity, Generation and Benefit-to-Cost Ratio Data.

Facility Name	Perm Disturbed Land (ha)	MW	Lifetime Electricity Generation GWh[a]	Land Occupation Value (ha/MW))	Benefit To Cost Ratio
Bison	129	114	28,706	1.1	2.15
Ashtabula I	94	76	19,318	1.2	2.15
Langdon	85	78	19,612	1.1	2.15
Rugby	75	58	14,658	1.3	2.15
Baldwin	66	40	10,067	1.7	2.15
Prairie Winds	47	45	11,355	1.0	2.15
Ashtabula II	38	47	11,797	0.8	2.15
Tatanka	33	36	8,995	0.9	2.15
Cedar Hills	26	8	1,917	3.4	2.15
Ashtabula III	25	24	6,194	1.0	2.15
Luverne	20	19	4,866	1.0	2.15
Oliver II	19	19	4,778	1.0	2.15

N. Dakota I & II	17	24	6,046	0.7	2.15
Oliver I	14	20	4,974	0.7	2.15
Velva	2	5	1,160	0.5	2.15

[a] Lifetime electricity generation is based on the wind farm nameplate capacity multiplied by the North Dakota wind capacity factor of 0.389 (US Energy Information Administration, 2012) for 8424 hours per year over a 30 year facility life span. 8424 generation hours per year is used based on 14 days downtime per year for servicing and maintenance.

The hourly land occupational value of North Dakota Wind Farms averages 1.2 hectares/megawatt. The analysis aligns with the study by NREL, which reported that the permanent land disturbances range from approximately 0.06 hectares/MW to approximately 2.4 hectares/MW for wind farms greater than 20 megawatts constructed between 2000 and 2008 in the United States (Denholm, 2009). Although NREL did not use data from most of North Dakota's wind farms, very specific satellite imagery to measure direct land consumed was used and found that the feasibility values fall within the range of the national average.

Deviations from a linear trend line can be attributed to factors such as the manufacturer, make and size of the wind turbines and age of the wind farm as efficiencies in design, development and construction increased as more wind farms were erected.

7.6 Anaerobic Digester Results

The primary dairy farm revenue stream is the sale of milk products. Costs related to a dairy farm include operating costs such as feed, veterinary and medicine, allocated overhead, etc. which are identified in Table 10. Adding an AD facility to an existing dairy farm will not only offset electricity costs but it will provide environmental benefits such as GHG abatement, organic waste reduction, groundwater pollution mitigation, pathogen destruction and odor reduction.

Table 10. Typical Dairy Farm Costs

U.S monthly dairy costs of production per cwt of milk sold, 2014[a]	**Average**
Operating costs:	$/cwt
Feed	9.15
Veterinary and medicine	0.78
Marketing	0.24
Repairs	0.56
Total operating costs	10.74

Allocated overhead:	
Hired labor	1.53
Opportunity cost of unpaid labor	2.29
Capital recovery of machinery and equipment	3.69
Taxes and insurance	0.20
General farm overhead	0.71
Total, allocated overhead	8.41

Table 10 (continued)

Total costs listed	19.2

[a] Data are based on the U.S., monthly dairy costs of production per cwt of milk sold, 2014 (USDA, 2014).

Anaerobic digesters make several contributions to climate change mitigation. The digesters capture biogas that would have been emitted because of the nature of organic waste management at the farm where the digester is in operation. By capturing and combusting biogas, anaerobic digesters are preventing fugitive methane emissions. Methane is a potent GHG with a global warming potential 34 times that of CO_2 (Myhre and Shindell, 2013). Another benefit of anaerobic digesters is the displacement of fossil fuel-based energy that occurs when biogas is used to produce heat or electricity. Biogas is generally considered to be a carbon-neutral source of energy because the carbon emitted during combustion was atmospheric carbon that was recently fixed by plants or other organisms, as opposed to the combustion of fossil fuels where carbon sequestered for millions of years is emitted into the atmosphere. As such, substituting energy from biogas for energy from fossil fuels cuts down on GHG emissions associated with energy production. GHG emissions are also reduced when the nutrient-rich digestate created from anaerobic digestion is used to displace fossil-fuel based fertilizers used in crop production (Centre for Climate and Energy Solutions, 2015).

Anaerobic digesters can reduce nutrient runoff from farms into waterways due to the containment of manure. The runoff and leaching of phosphorous from land, increases eutrophication (nutrient loading) and the potential for water pollution in local waterways. Additionally, utilizing manure decreases the time it sits at the farm contributing to odor and pest issues (e.g., as a breeding ground for pests and disease vectors) (Global Methane Initiative, 2013).

Bedding for the cows is also a cost to dairy farmers. With anaerobic digesters, the effluent is suitable for animal bedding and saves $23.25 per cow per year (Tonneson, Lon, 2007).

AD facilities are also eligible for carbon credits since they remove greenhouse gases from the environment. A credit is a measure representing one megatonne (a mass equal to 1,000 kilograms) of carbon dioxide. This is either saved from being emitted or removed from the Earth's atmosphere (Wisler, 2015). The price paid for carbon credits fluctuates in a dynamic market but in 2012, the price paid for each credit was $5.90 in the Voluntary Market (Lang, 2013). This price was used in the business model as an example of revenue that could be achieved in the voluntary market.

The AD facilities studied all had similar benefit-to-cost ratios ranging from 1.20 to 1.25. Table 11 shows revenues and costs for the studied AD facilities.

Table 11. Revenues and Costs for Studied AD Facilities.

Facility Name	**Cows**	**Annual Electricity Revenue[a] ($K)**	**Annual Milk Revenue [b]($K)**	**State Electricity Revenue Incentive[c] ($K)**	**Annual Bedding [d] ($K)**	**Carbon Credits[e] ($K)**	**Installed Capital Cost[f] ($M)**	**Annual Loan Payment [g] ($K)**
Northern Plains Dairy	3000	$143	$15,492	$25	$70	$20	$12	$261
Midwest Dairy Institute	2000	$207	$10,328	$0	$50	$13	$8	$209
Haubens-child Farms	900	$85	$4,647	$15	$21	$6	$8	$78
District 45 Dairy	5520	$1,174	$28,504	$204	$128	$36	$6	$480

[a] Annual electricity revenue is based on the AD nameplate capacity multiplied by an average capacity factor of 0.73 (Krom, 2008) for 8760 hours per year at $0.0862 per kWh (Otter Trail Power Company, 2014).
[b] Annual milk revenue is calculated based on $23.20/cwt (USDA, 2014). CWT is determined by multiplying the average annual output per cow of 22, 258 pounds of milk (USDA, 2014) by the number of cows and dividing by 100.
[c] State of Minnesota anaerobic digestion electricity generation incentive of $0.015/kWh (DSIRE, 2014).
[d] AD digestate is used for animal bedding which saves $23.25 per cow annually (Tonneson, 2007).
[e] Carbon credits calculated based on $5.90 per credit (Lang, 2013).
[f] Based on the midpoint project data costs of $1500/cow from AgStar.
[g] Annual loan payment based on a 30 year loan obtained for 90% of the installed cost at a 5% interest rate.

A sensitivity analysis was performed on milk revenue, annual farm costs, electricity price, loan interest rate, state incentives and capital cost variables to see which had the greatest impact on the benefit-to-cost ratio. Figure 33 summarizes the sensitivity analysis.

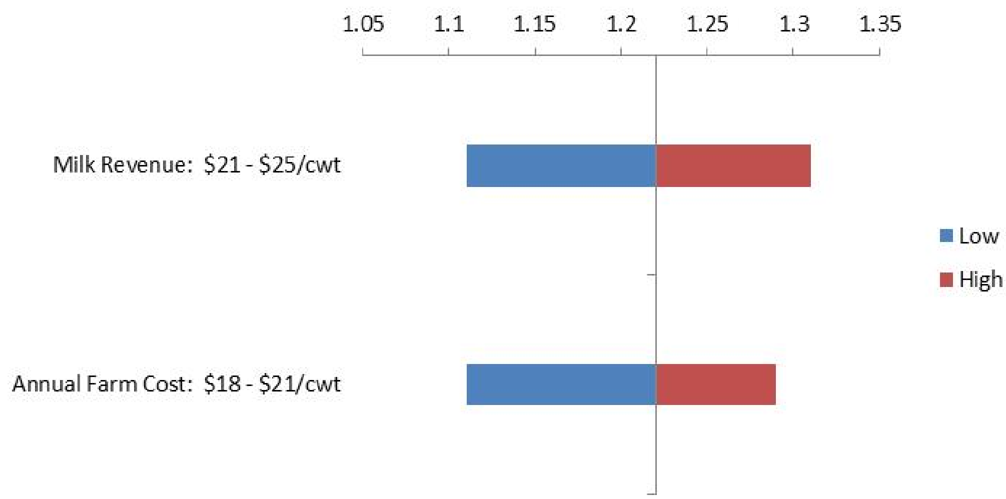


Figure 33. AD Sensitivity Analysis of Benefit-to-Cost Ratio Input Variables.

Analyzing each variable independently, the price of milk had the greatest impact on the benefit-to-cost ratio range (1.11 to 1.31), followed closely by annual farm costs (1.11 to 1.29). Unlike the wind sensitivity analysis, interest rates, state incentives for electricity production by AD and capital cost had very minimal impact (1.21 to 1.22) on the benefit-to-cost ratio.

The Anaerobic Digester Facilities studied have a benefit-to-cost ratio between 1.20 and 1.25 and use between 14 and 105 hectares of permanently disturbed land as shown in Figure 34 and Table 12. See Appendix AA through AD for additional data.

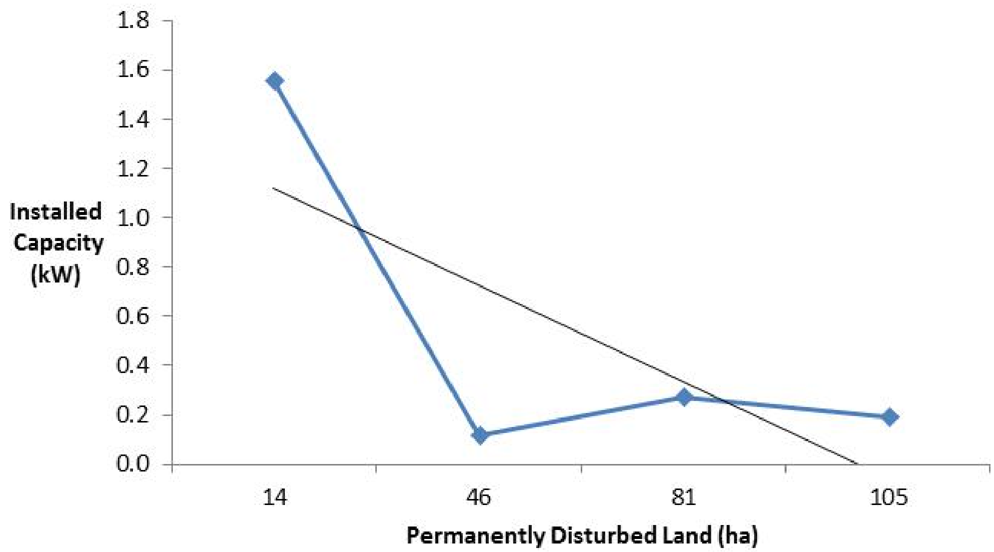


Figure 34. Installed Capacity vs. Permanently Disturbed Land of Studied AD Facilities.

Table 12. Studied AD Facility Land, Capacity, Generation and Benefit-to-Cost Ratio Data.

Facility Name	**Perm Disturbed Land (ha)**	**MW**	**Lifetime Electricity Generation GWh[a]**	**Land Occupation (ha/MW))**	**Benefit To Cost Ratio**
Northern Plains Dairy	105	0.2	48	551	1.20
Midwest Dairy Institute	81	0.3	69	297	1.21
Haubenschild Farms	46	0.1	29	405	1.22
District 45 Diary	14	1.6	393	9	1.25

[a] Lifetime electricity generation is based on the AD nameplate capacity multiplied by the capacity factor of 0.73 (Krom, 2008) for 8424 hours per year over a 30 year facility life span. 8424 generation hours per year is used based on 14 days downtime per year for servicing and maintenance.

AD land occupation values vary greatly between facilities and are all significantly higher than wind energy. The size of the dairy farm herd will affect the land occupation value as well as the waste management system employed. Anaerobic digesters may still be well worthwhile as part of an existing agro-ecosystem infrastructure currently in place on dairy farms. Manure is typically added to the digester daily via a manure flushing system that is likely to be already utilized on the dairy farm (Goodrich, 2005).

There has been a steady decline in the number of dairy farms in the United States since 2002 (USDA, 2014). One of the contributing factors to this decline is the continuing struggle for profitability. Ironically, adding an AD facility only slightly alters the benefit to cost ratios of the dairy farms studied as shown in Table 13.

Table 13. Benefit-to-Cost Ratios of Studied Diary Farms with and without AD.

Facility Name	**Number of Cows**	**Benefit-to-Cost Ratio Without AD**	**Benefit-to-Cost Ratio With AD**
Northern Plains Dairy	3000	1.21	1.20
Midwest Dairy Institute	2000	1.21	1.21
Haubenschild Farms	900	1.21	1.22
District 45 Dairy	5520	1.21	1.25

Since all 50 states and Puerto Rico currently have dairy farms (Dairy Farming Today, 2014), federal and state incentives would have a significant impact on profitability, which could reverse the declining trend in dairy farming. Anaerobic digesters are a tremendous renewable energy resource for lands already dedicated to agriculture. In addition to providing odor abatement when using wastes as a feedstock, the resulting biogas can be combusted to run a generator producing electricity and heat (called a co-generation system), burned as a fuel in a boiler or furnace, or cleaned and used as a natural gas replacement.

One of the main reasons that there are so few commercial dairy anaerobic digester systems currently in North Dakota is the lack of support by incentives provided by North Dakota's Renewable Portfolio Standards. North Dakota does not have a state specific mandated RPS, rather it has a non-binding renewable energy goal to generate 10 percent of the electricity sold in the state by 2015 (DSIRE, 2014). As of 2013, 16% of North Dakota's net electricity generation was from wind (US Energy Information Administration, 2014). With only a voluntary goal coupled with among the lowest electricity prices in the country and a large percentage of North Dakota's electricity generated from coal-fired power plants, there are no financial incentives to utilize only AD systems to generate electricity.

South Dakota, which has one of the nearest anaerobic digester projects in close proximity to North Dakota, also has a voluntary 10 percent goal by 2015 (DSIRE, 2014). South Dakota currently generates 53.5% of its electricity by hydroelectric and 4.9% from wind (Institute for Energy Research, 2014). But unlike North Dakota, South Dakota is an observer of the Midwestern Regional Greenhouse Gas Reduction

Accord. The Accord was signed in November 2007 as a part of the Midwestern Governors Association Energy Security and Climate Change Summit to set regional GHG emission reduction targets and develop a multi-sector cap-and-trade system and complementary policies to help achieve these targets (Centre for Climate and Energy Solutions, 2014) which demonstrates the state's commitment to alternative energy and the environment.

In contrast, Minnesota, which has 3 of the 4 closest anaerobic digester projects in proximity to North Dakota, has a state mandated RPS of 31.5% of total retail electricity sales by 2020. The eligible renewable technologies specifically include anaerobic digestion in the applicable sectors of municipal utility, investor-owned utility, and rural electric cooperatives (DSIRE, 2014).

Further analysis was performed to calculate the levelized cost of energy (LCOE), which is defined as the net cost to install a renewable energy system divided by its expected life-time energy output. The Cost of Renewable Energy Spreadsheet Tool (CREST) which was developed by the National Renewable Energy Laboratory (NREL) was used (NREL, 2010). Inputs into the CREST tool include data on the wind farm and AD facility's performance, cost, operation, tax and finances. The output includes the calculated LCOE. The LCOE for Langdon and all of the other North Dakota Wind Farms studies were all \$0.0275/kWh. The output LCOE for Haubenschild Farms is \$0.0415/kWh. Each AD facility had a different LCOE calculation as summarized in Table 14:

Table 14. Studied AD Facilities LCOE Calculations.

Facility Name	**LCOE ₡/kWh**	**Financial Incentive Needed to Equal Wind LCOE[a]**
Northern Plains Dairy	9.45	39%
Midwest Dairy Institute	5.15	25%
Haubenschild Farms	4.15	16%
District 45 Dairy	1.15	None

[a] Financial incentives are based on the percentage of capital cost needed to offset the total capital cost such that the AD LCOE equals the Wind LCOE of 2.75 ₡/kWh. Grants and in-kind assistance are based on similar incentives by AgSTAR and state programs described by Lazarus and Rudstrom (2007).

LCOE is a convenient summary measure of the overall competiveness of different generating technologies (US EIA, 2015). Since the AD facilities LCOE varies significantly as compared to the wind farm's steady LCOE of 2.75 ₡/kWh, each AD facility must be analyzed to determine if the investment decisions are viable for each specific dairy farm. However, in a study by Lazarus and Rudstrom, AgSTAR and the Minnesota Department of Agriculture provided financial and technical assistance to an 800-cow dairy farm in Minnesota. These incentives were reportedly motivated by policymakers' and the utility's desire to demonstrate the viability of the technology and motivate other farms to follow suit. The grants and assistance amounted to over 36% of the capital investment (Lazarus and Rudstrom, 2007). Each AD facility studied was then analyzed to determine the financial incentives necessary to be comparable with the wind LCOE as shown in Table 14. The variations in incentives necessary to compete with wind range from a worst case of 39% of the capital costs to a best case of AD being more competitive than wind. This shows that one flat incentive rate would not be applicable to all AD projects due to the broad range of AD variabilities affecting cost competitiveness.

7.7 Policy Implications and Conclusion

There is tremendous possible capacity for wind power in the Great Plains of the United States. North Dakota in particular already produces about four percent of the United States' electricity from wind power (US DOE, 2015) but has the theoretical potential, even after subtracting land that is unsuitable for energy development, of 770,000 megawatts (MW) which is a capacity higher than all the combined fossil-fueled power plants in the U.S. (NRDC, 2014). However, with all of North Dakota's wind potential, it ranks only 11th in the U.S. for installed wind capacity (American Wind Energy Association, 2013).

The Northern Great Plains (NGP) region has the environmental conditions conducive to biogas production of anaerobic digestion biomass feedstock from farm animal wastes as well as fuel crops (South Dakota State University, 2007). Biogas recovery systems utilizing anaerobic digesters are estimated to be technically feasible at over 8200 dairy and swine operations in the United States. Biogas recovery systems at these facilities have the potential to collectively generate over 13 million megawatt-hours (MWh) per year (AgSTAR, 2013). However, from 2000 to 2015, the number of dairy farms in North Dakota has dropped from 350 to 91 (Farm Journal, 2015). In the early 1990's there were about 1600 dairy farms (Heinrich, 2012).

Based on the results of wind farms and AD facilities, significantly more energy and revenue can be generated per hectare of land using wind energy as opposed to AD. However, by taking into consideration land use, land intensity and project economics, the integration of anaerobic digestion and wind energy can be used together to address both the economic and environmental challenges using renewable energy as a solution for North Dakota dairy farmers. This integrated solution enables the higher benefit-to-cost ratio of wind to offset some of the cost challenges faced by dairy farmers and REAs. Wind turbines placed on dairy farms could negate electricity costs associated with the farm and AD facility and provide another potential revenue stream for the farmers while producing biogas to be sold to the REAs. Combining the smaller land occupational values of wind farms with the larger values for AD would provide an average land occupational value more conducive to profitability than AD alone. Changes in North Dakota state legislature such as instituting mandatory RPS requirements instead of goals, feed-in tariffs, grants, subsidies or other forms of financial assistance similar to the state of Minnesota could provide the incentives to existing dairy farmers to implement such combinations of wind and AD projects. These incentives could compensate for the associated capital costs while providing another renewable energy source to North Dakota's portfolio while realizing the additional benefits of odor abatement, reduction in hazardous runoff and producing fertilizer and bedding material. Changes to the state RPS may have a more favorable political impact to state citizens instead of the current path of the North Dakota state senate office, which is attempting to pass legislation to counter a 1932 anti-corporate farming law which was first instituted to protect family owned farms from corporately owned dairy farms (Associated Press, 2015).

CHAPTER 8: INTRAPRENEURSHIP BUSINESS MODEL

After the feasibility studies are complete, the next step is to develop a business model to demonstrate the financial viability of the integrated renewable energy solution as shown in Figure 35.

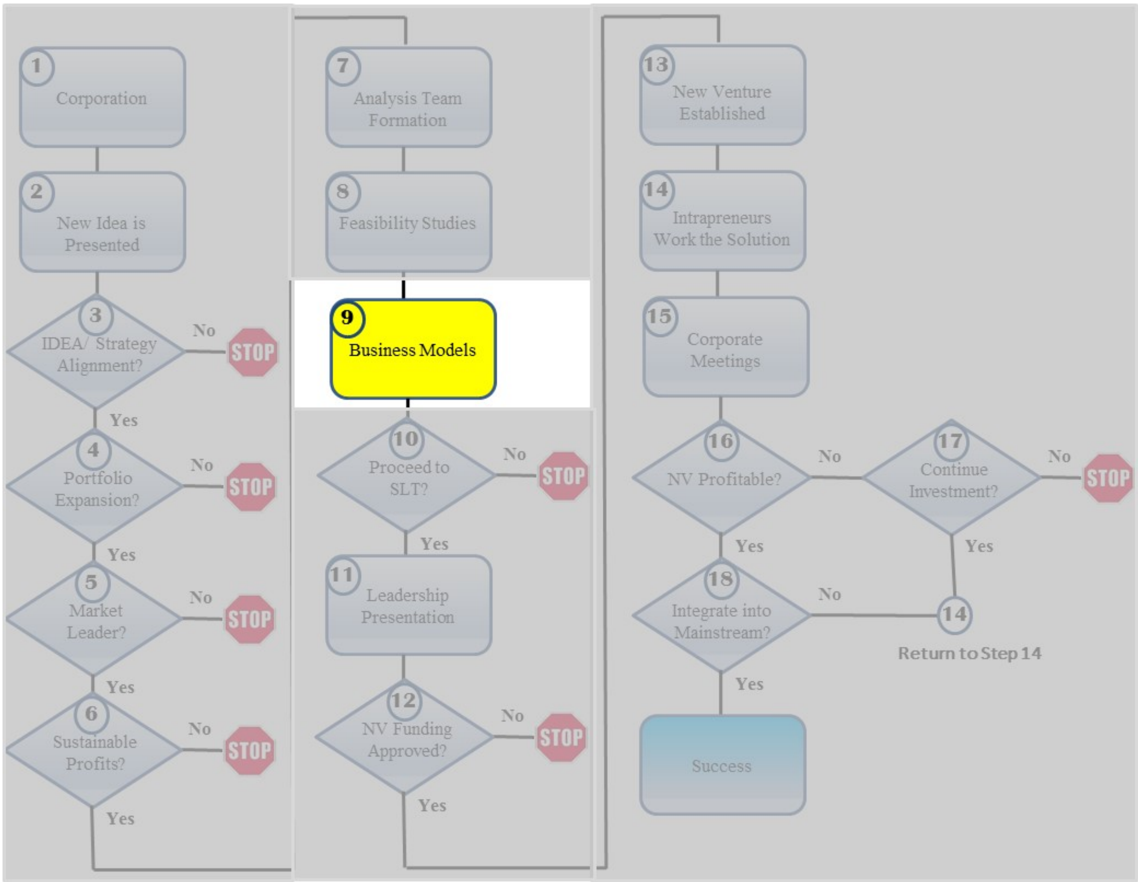


Figure 35. Intrapreneurship Business Model.

8.1 Introduction

The previous feasibility studies confirm that the Great Plains feedstock and wind energy abundance can provide an integrated renewable energy technology solution combining wind and anaerobic digestion utilizing animal waste feedstock. This solution is viable for two main reasons:

- Local power demand to a large entity such as a Rural Electrification District will be met.

- Excess power produced will be stored as syngas which will not burden the Grid and will capitalize on the natural variations in power demand and wind availability.

Using the data from the feasibility studies, a business model has been developed to analyze the integrated solution optimizing both the wind energy and anaerobic digestion variables. The outputs of the model will allow the intrapreneurs of this idea to determine the financial viability and better understand the economics and assist in financial decision making. This information will be necessary when presenting the idea and solution to corporate senior leadership for a new venture.

The business model will assist with determining if the integrated renewable energy solution can overcome the many technical challenges in supplementing conventional sources to supply a regional grid servicing distant markets reliably and economically. The previous feasibilities have determined that in the High Plains of the United States, wind resources are fairly constant, but even so, the wind speed is not reliable enough to satisfy real-time local sales demand, unless excess capacity is installed, i.e., more turbines than required even for peak demand. Moreover, in low wind, all units operate less efficiently. However, where the cost of distributing power exceeds the cost of generation, as can occur in rural areas, renewables could be economical if the availability to meet demand was reliable. This is generally the case if electricity is generated by combustion of local biofuels. This integrated solution approach is to utilize both wind energy and anaerobic digestion (AD) such that excess power produced in high winds can be stored or used in other applications. This stored energy can be used in processes that tolerate interruptible and variable supply such as the production of biogas from anaerobically digested dairy cow manure. This will maintain local power supply reliability in periods of sparse wind and support export or local use as fuel.

The biogas that is produced when AD exothermally converts feedstock using power from the excess wind energy exceeding demand in essence becomes energy storage. Biogas is a clean environment friendly fuel containing about 55–65% methane (CH_4), 30–45% carbon dioxide (CO_2), traces of hydrogen sulfide (H_2S) and fractions of water vapors. Biogas can be utilized in internal combustion engines and turbines to produce electricity for both local distribution in low wind periods, and also to run AD stirrers and other equipment. Heat from the engines and turbines can be used to produce hot water and maintain AD digester temperatures. However, the presence of incombustible gases like CO_2, H_2S and water vapor reduce its calorific value and make it uneconomical to compress and transport long distances. It is therefore necessary to remove these components before compression, if the biogas will be exported (USDA, 2013). The lower calorific value of biogas from AD is 23 MJ/Nm^3 (Hallgran, 2009). In high wind, the excess power can also be used to clean and desiccate the biogas, and remove the CO_2 fraction. An optimization analysis will be developed as part of the business model to determine how many wind and AD powered turbine-generators are needed to provide a particular level of reliability for a given pattern of demand intensity.

For this business model, manure from dairy cows is used for the feedstock into the anaerobic digesters since manure is easily collected on dairy farms where cows are confined. A 1,500 pound dairy cow produces about 125 pounds of manure daily (Abraham, 2002) and the Great Plains could produce over 60 million cubic feet of biogas daily which is equivalent to 10 GWh of electricity. AgSTAR estimates that there are now 202 anaerobic digester systems operating at commercial livestock farms in the United States while they are technically feasible at over 8200 farms in the United States (US EPA, 2013).

8.2 Business Need for an Integrated System

A business and technical solution consisting only of wind energy produces variable output that is dependent on the wind intensity and each wind turbine's capacity factor. Figure 36 illustrates a typical wind turbine's power output based on wind speed (Pela Flow Consulting, N.D.).

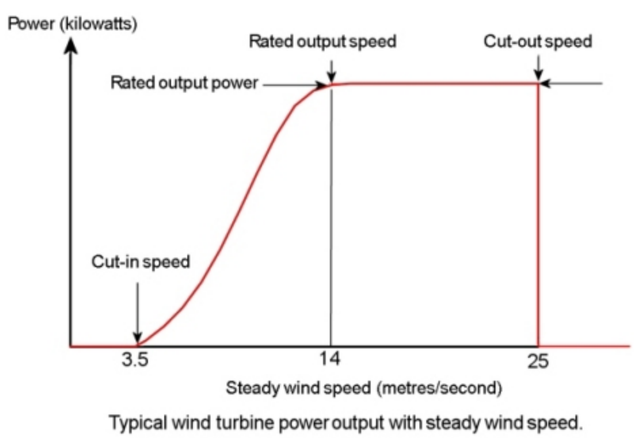


Figure 36. Typical Wind Turbine Power Output (Pela Flow Consulting, N.D.).

The rated capacity of a wind turbine is only achieved within a range of steady wind speeds between the rated output speed and cut-out speed. The cut-out speed is the speed of the wind that can cause damage to the turbine so a braking system is employed to stop the rotor. The cut-in speed is the speed of the wind where the wind turbine starts to rotate and generate electricity. On average, wind turbines do not generate near their capacity. Industry estimates project an annual output of 30-40%, but real-world experience shows that annual outputs of 15-30% of capacity are more typical (National Wind Watch, N.D.).

If the energy solution is based solely on wind power, satisfaction of local demand will not be met unless excess capacity is installed which directly impacts the capital cost and return on investment of the project. There will also be periods when wind energy is wasted when output exceeds demand. These variabilities between demand and output, while currently a nuisance to grid operators, become a benefit of an integrated "hybrid" renewable energy solution. Such a solution does not negatively impact the electrical grid transmission and distribution infrastructure. To accomplish this, excess wind power that exceeds demand will be used to power anaerobic digesters. The biogas that is produced from the anaerobic digesters powered by the excess wind energy exceeding demand in essence becomes energy storage.

8.3 Integrated Renewable Energy Business Model

There are currently 91 dairy farms throughout North Dakota (AgWeb, 2015). Because dairy farm sizes vary drastically, the business model is designed for flexibility. Anaerobic digesters have been proven to provide economic and environmental benefits on farms with as few as 100 dairy cows (Goodrich, 2005) as well as communal digesters serving multiple farms totaling over 15,000 cows (Cooper, 2012).

The first step of the business model determines the power requirements for the anaerobic digester equipment. For this example, we chose a 1000 milk cow dairy farm but the model is flexible to account for any size dairy farm. The majority of required power is used by supplemental heat for the digesters due to the North Dakota environment. Table 15 illustrates the major subsystems and the average power consumption for the 1000 cow anaerobic digester system.

Table 15. Anaerobic Digester System Power Consumption.

Equipment	kW	Operational Hours/year	MWh/year
Submersible Mixer	35	4380[a]	153
Agitator	10	8424[b]	84
Supplemental Heat	240	6570[c]	1577
Pumps (100 HP)	74	1095[d]	81
Gas Cleaning and Handling Equipment	70	7008[e]	491
Gas Pressurization Equipment	30	7008[e]	210
Total			2596

[a] Based on half-time use per year (Renewable Energy Concepts, N.D.)
[b] Based on full time use minus two weeks per year downtime for maintenance and servicing (Renewable Energy Concepts, N.D.).
[c] Based on three-quarter use per year (Sustainable Conservation, 2014).
[d] Based on pumps operating once every eight days (Electrigaz Technologies, 2008).
[e] Based on equipment operating 80% full time (Electrigaz Technologies, 2008).

The total electric power needed for the AD system is 2596 MWh/year. On average, dairy farms use between 677 to 934 kWh per cow per year (TheCattleSite, 2014). For this analysis, the midpoint electricity usage of 806 kWh per cow per year was chosen. For the 1000 milk cow dairy farm, the average annual electricity consumed is 806 MWh/year. Total electricity needed is therefore 3402 MWh/year. The second step of the business model determines the minimum wind turbine size to provide the required power for the anaerobic digester system. Additional wind turbines may be added as desired. Table 16 shows the average yearly electricity generated by various sized wind turbines based on 8424 operational hours per year (14 days out of service per year for maintenance and service). The North Dakota capacity factor for wind turbines is 0.389 (US Energy Information Association, 2012).

Table 16. Average Electricity Generated in North Dakota by Various Sized Wind Turbines.

Wind Turbine Nameplate Capacity	Electricity Generation MWh/year[a]
500 kW	1638
750 kW	2458
1 MW	3277
1.5 MW	4915
2 MW	6554
3 MW	9831

The wind turbine that provides the closest electricity generation to power the AD system and dairy farm of 3402 MWh/year is the 1.5 MW turbine which generates 4915 MWh/year. Excess power from the

1.5 MW wind turbine will also allow the project to power the farm house and other miscellaneous equipment potentially eliminating the owner's electrical dependence from the local utility. Depending on the utility and local legislation, the excess power could be sold back to the utility providing an additional revenue stream for the dairy farm.

The third step of the business model determines the capital costs of the integrated renewable energy solution based on the sizes of equipment selected previously as detailed in Table 17.

Table 17. Integrated Renewable Energy Solution Capital Costs.

Capital Costs				**Subsidies**[f]	
AD System for 1000 Diary Cows		1.5 MW Wind Turbine[d]		Federal Subsidy (30%)	$ 997,854
Capital Cost[a]	$ 974,757	Rotor	$ 313,993	USDA Subsidy (25%)	$ 831,545
Solid Separator[b]	$ 116,971	Drive Train, Nacelle	$ 817,441		
Biogas Upgrade Equipment[c]	$ 332,676	Control System	$ 46,370		
Gas Grid Connection[c]	$ 72,991	Tower	$ 194,755		
Subtotal	$ 1,497,395	Foundation	$ 60,944		
		Civil Work[e]	$ 104,664		
		Transportation	$ 66,243		
		Assembly & Installation	$ 50,345		
		Electrical Interface & Connections	$ 131,633		
		Engineering & Permitting	$ 42,396		
		Subtotal	$ 1,828,784		
Total without subsidies			**$ 3,326,179**	**Total with subsidies**	**$ 1,496,780**

[a] Capital Costs are based on the net present value of a regression of thirteen mixed digesters at $320,864 + $563 per cow (eXtension, 2014).
[b] Solid Separator is based on 12% of the capital cost of the anaerobic digester project (eXtension, 2014).
[c] Based on the net present value of Electrigaz Technologies feasibility study (Electrigaz Technologies, 2008). Due to the local gas grid connection, biogas storage systems are not necessary for this project.
[d] Based on NRELwind turbine design cost and scaling model (Fingersh, 2006).
[e]Civil work encompasses underground utility routing, grading, drainage, access roads, foundations, etc.
[f]For this example project, it is assumed that the maximum subsidies will be realized.

To offset capital costs and incentivize renewable energy technologies, there are subsidies that are available that have the potential to compensate for a major portion of the initial capital. There are up to 30% federal Treasury Department subsidies and up to an additional 25% subside from the USDA (Bennett, 2011). For this example project, grants in the amount of $1.5M could be realized, assuming that the maximum subsidies are awarded, which would reduce the capital costs to approximately $1.5M from $3.3M.

Revenue generated from the processed biogas will be approximately $70K to $75K per year based on 40K ft^3 per day and 14.6 Mft^3 per year being sold at a value of $5.03/$kft^3$ (US EIA, 2012). Electricity savings are on the order of $300K per year based on $0.0856/kWh (US EIA, 2010). Other potential revenue sources not factored are the sale of animal bedding, liquid, and dry fertilizers that are natural by-products of the anaerobic digestion. For this analysis, it is assumed that the additional revenue sources would offset the yearly operations and maintenance costs for both the wind turbine and anaerobic digester system.

The output of the business model provides the estimated electricity savings by using wind to power the anaerobic digestion equipment, estimated electricity revenue from the surplus power generated from the wind turbine(s), revenue from biogas production, carbon credits, and finally, the expected payback period. AD facilities are eligible for carbon credits since they remove greenhouse gases from the environment. A credit is a measure representing one megatonne (a mass equal to 1,000 kilograms) of carbon dioxide. This is either saved from being emitted or removed from the Earth's atmosphere (Wisler, 2015). The price paid for carbon credits fluctuates in a dynamic market but in 2012, the price paid for each credit was $5.90 (Lang, 2013).

The output from our 1000 cow dairy farm example is shown in Table 18.

Table 18. Business Model Outputs.

Estimated Electricity Savings ($K/yr)[a]	**Estimated Electricity Revenue ($K/yr)[b]**	**Estimated Biogas Production Revenue ($K/yr)[c]**	**Carbon Credits ($K/yr)[d]**	**Payback Period (years)**
$222	$199	$73	$7	5

[a] Based on the anaerobic digester equipment yearly power consumption multiplied by the average electricity rate in North Dakota of $0.0856/kWh (Otter Trail Power Company, 2014).
[b] Based on the wind turbine(s) yearly output generation minus the AD yearly power consumption multiplied by the average electricity rate in North Dakota of $0.0856/kWh (Otter Trail Power Company, 2014).
[c] Based on the number of cows producing and average of 40 ft^3/day sold at a value of $5.03/$kft^3$ (US EIA, 2012).
[d] Based on removing 1100 megatonnes of carbon dioxide per year at $5.90 per credit (Lang, 2013).

8.4 Conclusion

Based on the Great Plains of the United States' abundant wind energy and biofuel feedstock supply, a renewable energy solution combining these plentiful resources could provide significant cost savings to the distribution cooperatives while increasing the reliability of the power contributors. The business model developed can be tailored to the specific requirements of each dairy farm to determine the size of the wind turbine(s) needed to offset electricity costs while also estimating the quantity of syngas produced from the AD facility. In our example of a 1000 milk cow dairy farm in North Dakota, we showed that one 1.5 MW wind turbine could be used to power the AD facility saving the dairy farm an estimated $200K per year in electricity costs while also providing a $200K yearly revenue stream via net metering to the local utility. In addition, approximately $75K in revenue can be achieved from selling biogas which can be used as transportable fuel. In essence this transportable fuel is the wind turbine(s) energy storage since the biogas can be transported and used to generate electricity via IC engines at different locations. The environmental benefits of removing 1100 megatonnes of carbon dioxide produce about $7K per year in carbon credits.

Thus, the payback period for the capital required for the integrated renewable energy solution is conservatively estimated to be 5 years for a 1000 cow dairy farm. Unfortunately, North Dakota does not have anaerobic digestion production tax credits like states such as Minnesota or the payback period would be even less and revenue generation would be more.

The business model and feasibility studies conclude that the intrapreneurs' idea and solution is both technically and financially viable on both individual farm solutions and large scale multiple farm solutions. There is now sufficient information to proceed to corporate senior leadership and present the overall solution as shown in Figure 37.

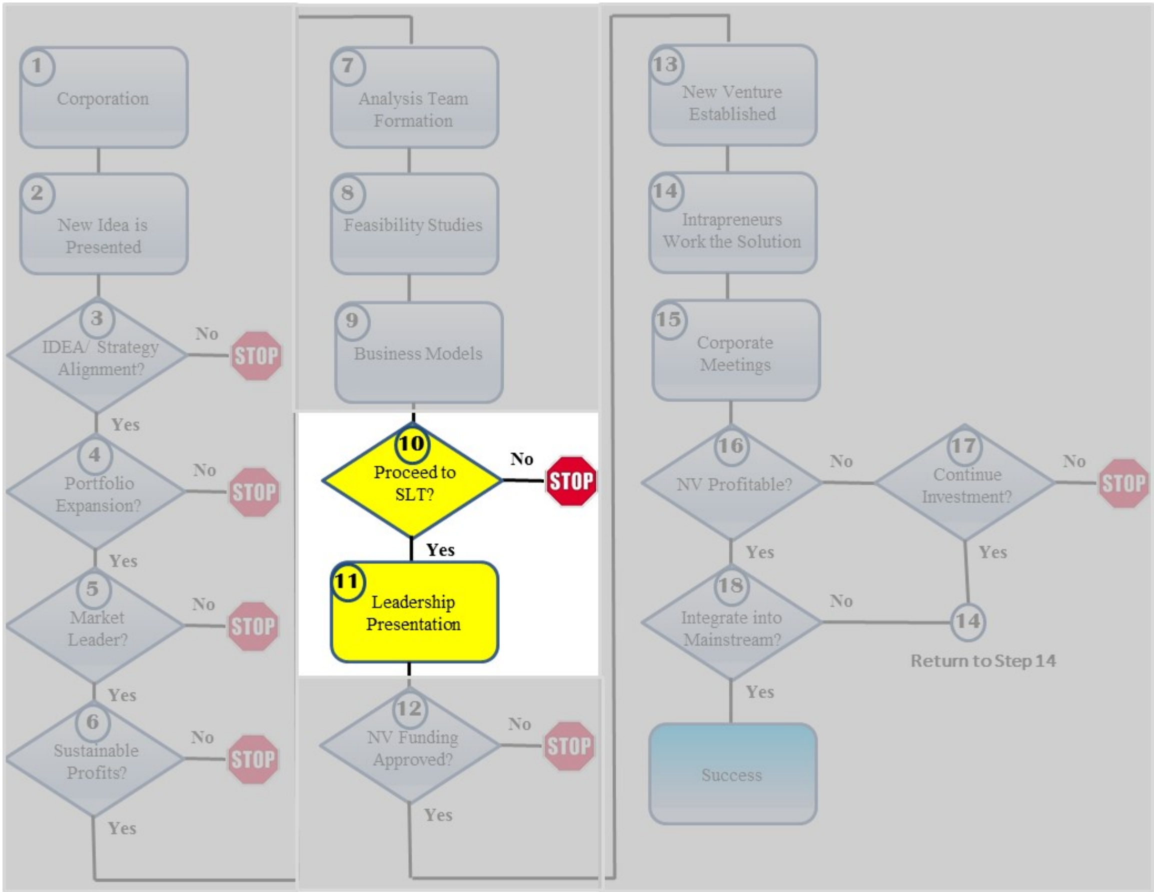


Figure 37. Business Models Showing Financial Viability and Feasibility Studies Showing Technical Viability Used to Present to Corporate Senior Leadership Prior to New Venture Approval.

CHAPTER 9: INTRAPRENEURSHIP RISK MANAGEMENT

Before corporate leadership will authorize funding for a new venture, as shown in Figure 38, corporate leadership will need to understand the opportunities, risks and risk mitigations for the new venture.

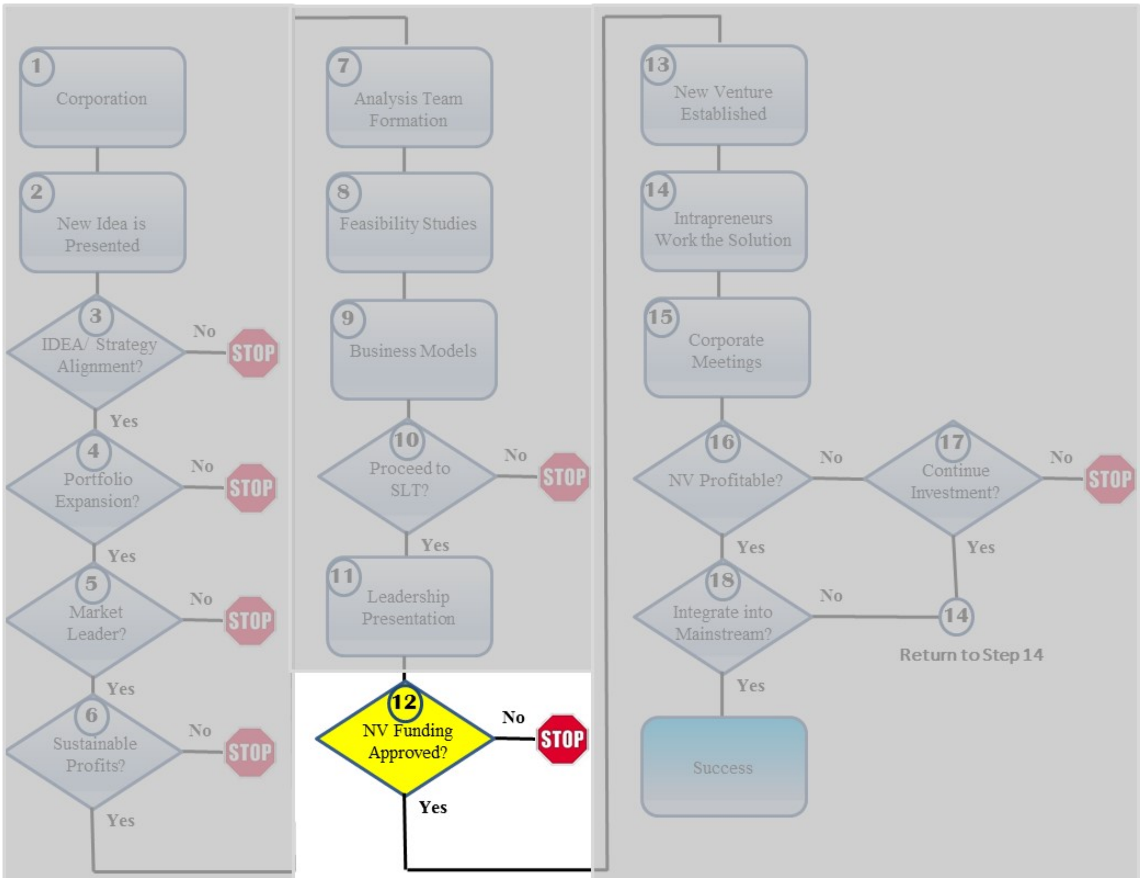


Figure 38. Risk Management is an Integral Factor in Determining if a New Venture will be Approved by Corporate Leadership.

9.1 Introduction

Strategic planning for intrapreneurs involves incorporating a SWOT analysis which can help identify the likely risks and rewards. SWOT stands for Strengths, Weaknesses, Opportunities and Threats, is an analytical framework that can help intrapreneurs face its greatest challenges and find its most promising new markets. SWOT analysis was created in the 1960s by Edmund P. Learned, C. Roland Christensen, Kenneth Andrews and William D. Book in their book "Business Policy, Text and Cases" (R.D. Irwin, 1969) -(Goodrich, 2015).

SWOT's primary objective is to help organizations develop a full awareness of all the factors, positive and negative, that may affect strategic planning and decision-making. This goal can be applied to almost any aspect of industry. SWOT is meant to be used during the proposal stage of strategic planning. It acts as a precursor to any sort of company action, which makes it appropriate for the following moments:

- Exploring avenues for new initiatives
- Making decisions about execution strategies for a new policy
- Identifying possible areas for change in a program
- Refining and redirecting efforts midplan

The SWOT analysis is an excellent tool for organizing information, presenting solutions, identifying roadblocks and emphasizing opportunities. It is widely accepted and focuses on key issues affecting a company. The purpose is to identify the strengths and weaknesses that are relevant to capitalizing on opportunities and mitigating threats. The SWOT tool has 5 key benefits:

- Simple to do and practical to use;
- Clear to understand;
- Focuses on the key internal and external factors affecting the company;
- Helps to identify future goals;
- Initiates further analysis (Jurevicius, 2013).

Strengths and weaknesses are internal to the company and can be directly managed, while the opportunities and threats are external and the company can only anticipate and react to them. When analyzing strengths, company assets that provide a competitive advantage are evaluated while weaknesses are listed as areas of focus for improvement where the company is lacking compared to the competition. Strength and weakness analysis should include:

- Resources such as land, equipment, knowledge, brand equity, intellectual property, etc.
- Core competencies
- Capabilities
- Functional areas: management, operations, marketing, finances, human resources and R&D

- Organizational culture
- Value chain activities (Jurevicius, 2013).

The analysis should include clear definitions that are specific. For example, “brand image” might be a weakness if the company has poor brand image. However, it can also be a strength if the company has the most valuable brand in the market, valued at $100 billion. Therefore, it is easier to identify if a factor is a strength or a weakness when it’s defined precisely.

In addition to clear definitions, another key factor in doing a SWOT analysis is to identify the factors that are the strengths or weaknesses in comparison to the competition. This is known as benchmarking. For example, 17% profit margin would be an excellent margin for many firms in most industries and it would be considered as a strength. But what if the average profit margin of your competitors is 20%? Then company’s 17% profit margin would be considered as a weakness.

A resource can be seen as a strength if it exhibits value; is rare; and cannot be imitated. This is known as VRIO framework.

Opportunities and threats are the external uncontrollable factors that usually appear or arise due to the changes in the macro environment, industry or competitors’ actions. Opportunities represent the external situations that bring a competitive advantage if seized upon. Threats may damage your company so you would better avoid or defend against them.

A PESTEL (political, economic, social, technological, environmental and legal) analysis represents all the major external forces affecting the company so it’s the best place to look for the existing or new opportunities and threats.

Competitor’s react to a company’s moves and external changes. They also change their existing strategies or introduce new ones. Therefore, the company must always follow the actions of its competitors as new opportunities and threats may open at any time.

The most visible opportunities and threats appear during the market changes. Markets converge, starting to satisfy other market segment needs with the same product. New geographical markets open up allowing the firm to increase its export volumes or start operations in a new country. Often niche markets become profitable due to technological changes. As a result, changes in the market create new opportunities and threats that must be seized upon or dealt with if the company wants to gain and sustain competitive advantage.

9.2 SWOT Template

The following guidelines are very important in writing a successful SWOT analysis as they eliminate most of SWOT limitations and improve it's results significantly:

- Factors have to be identified relative to the competitors. It allows specifying whether the factor is a strength or a weakness.
- List between 3 – 5 items for each category. Prevents creating too short or endless lists.
- Items must be clearly defined and as specific as possible. For example, firm's strength is: brand image (vague); strong brand image (more precise); brand image valued at $10 billion, which is the most valued brand in the market (very good).
- Rely on facts not opinions. Find some external information or involve someone who could provide an unbiased opinion.
- Factors should be action orientated. For example, "slow introduction of new products" is action orientated weakness.

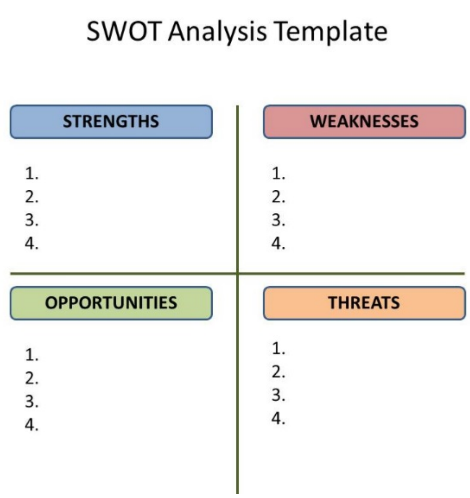


Figure 39. SWOT Template.

9.3 SWOT Example

An IBM SWOT analysis from 2013 is used as an example (Jurivecius, 2013) as shown in Figure 40:

Name	International Business Machines Corporation
Logo	IBM
Industries served	Computer hardware, Computer software, IT services, IT consulting
Geographic areas served	Worldwide
Headquarters	U.S.
Current CEO	Ginni Rometty
Revenue	$104.5 billion (2012)
Profit	$16.6 billion (2012)
Employees	434,246 (2012)
Main Competitors	Apple Inc., Cisco Systems, Inc., Dell Inc., Hewlett-Packard Company, Microsoft Corporation, Oracle Corporation, VMware, Inc. and many others.

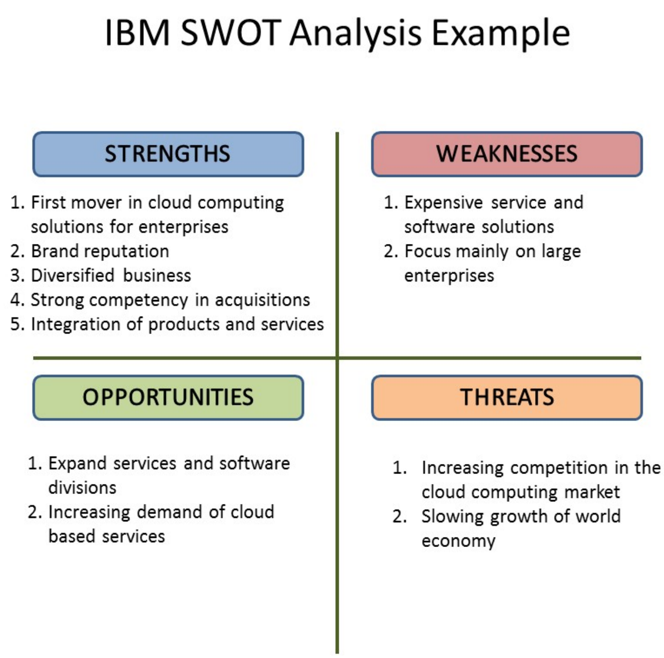


Figure 40. IBM SWOT Analysis Example.

Strengths:

1. **First mover in cloud computing solutions for enterprises.** IBM has moved to cloud computing in 2007 with its “Blue Cloud” program, which was designed to offer hardware and software solutions for enterprises that were willing to have their own private cloud. Since then the company has become the first reference point for enterprise cloud solutions in the cloud market. Unlike many other companies in the cloud market, the company has been offering the broadest range of software and services in one place.
2. **Brand reputation.** IBM has a significant market reach all over the world in all of the markets it operates. Company has also been awarded as #1 company for leaders; #1 green company worldwide; #2 most respected company; #5 most admired company; and has received many more awards This has resulted in a very positive and strong brand reputation. According to Interbrand, IBM brand was value at $75.5 billion in 2012 and was the 3rd most valuable brand in the world. Brand reputation significantly influences consumers’ decision to buy the product and IBM clearly benefits from that.
3. **Diversified business.** IBM segments its business into 4 divisions: Hardware, Software, Services and Financing. In 2000, the company was earning 35% of its income from hardware sales, where profit margins are low and future market growth is slow or negative. IBM has diversified from hardware to software business, which is expected to generate 50% of company’s income by 2015. This shift will result in lower impact of the negative trends in hardware market and higher profitability from sales of software and services. The company has also diversified geographically and now earns more than 60% of its income from outside US. IBM heavily invests into China and the rest of Asia to increase the geographic diversity of its income.
4. **Strong competency in acquisitions.** Over the last 13 years, from 2000 to 2012, IBM has acquired more than 140 companies in strategic areas including analytics, cloud, security and commerce. This has led to substantial growth in software and consulting offerings from IBM and established the company as a leading software and consulting provider for enterprises. IBM also expects to invest $20 billion over the next two years on acquisitions to strengthen its product portfolio even further. Company’s competence in successful acquisitions is the key advantage other companies, like HP, currently lack.

5. **Integration of products and services.** IBM offers hardware (servers, storages), software (enterprise content, service and information management) and services (cloud, software, data centers) all related to each other, which enable the company to provide one stop solution for enterprises and integrated product for the customers.

Weaknesses:

1. **Expensive service and software solutions.** IBM offers expensive integrated custom solutions for enterprises that want to build reliable IT infrastructure in their companies. This often involves buying hardware, software and services from IBM at the same time, which is very costly expenditure for any size of enterprise. Such an infrastructure investment is often postponed in times of uncertainty or slowing economy growth. This weakness was evident over the last few years, when IBM struggled to cross sell its products and saw decreasing revenues in the same period.
2. **Focus mainly on customized products.** IBM focuses on providing customized solutions for large and medium enterprises. This is a very profitable business model but captures only a small share of the market. The rest of the market is often satisfied with off-the-shelf software products and services. The lack of these products makes IBM less approachable by the rest of the market, where competitors like Oracle and SalesForce thrive.

Opportunities:

1. **Expand services and software divisions.** IBM provides various services (cloud, security and infrastructure) and enterprise solutions (servers, networking and storage), which are the most profitable IBM's businesses at the moment. The company should focus on growing these divisions as they promise better growth opportunities and higher profit margins.
2. **Increasing demand of cloud based services.** The cloud computing market is expected to grow by an average of 22% each year from 2011 to 2020. By 2020, the market is expected to reach $240 billion value. Currently, IBM is offering many services related with cloud computing and is well positioned to benefit from the growing market.

Threats:

1. **Increasing competition in cloud computing market.** Cloud computing market is new and lucrative market that has a lot of growth potential. The possible profits attract many newcomers and startups and threaten to take the market share from the incumbent IBM.
2. **Slowing growth of world economy.** As mentioned earlier, IBM sales heavily depend on the enterprises' willingness to make huge investments into IT infrastructure, which is far from the first option during the times of slow economy growth. While this scenario is not forecasted for the whole world during 2013 and 2014, some regions, like Europe, will still struggle to grow.

9.4 Intrapreneurship New Venture SWOT Analysis

A SWOT analysis of the intrapreneurship new venture is shown in Figure 41 below:

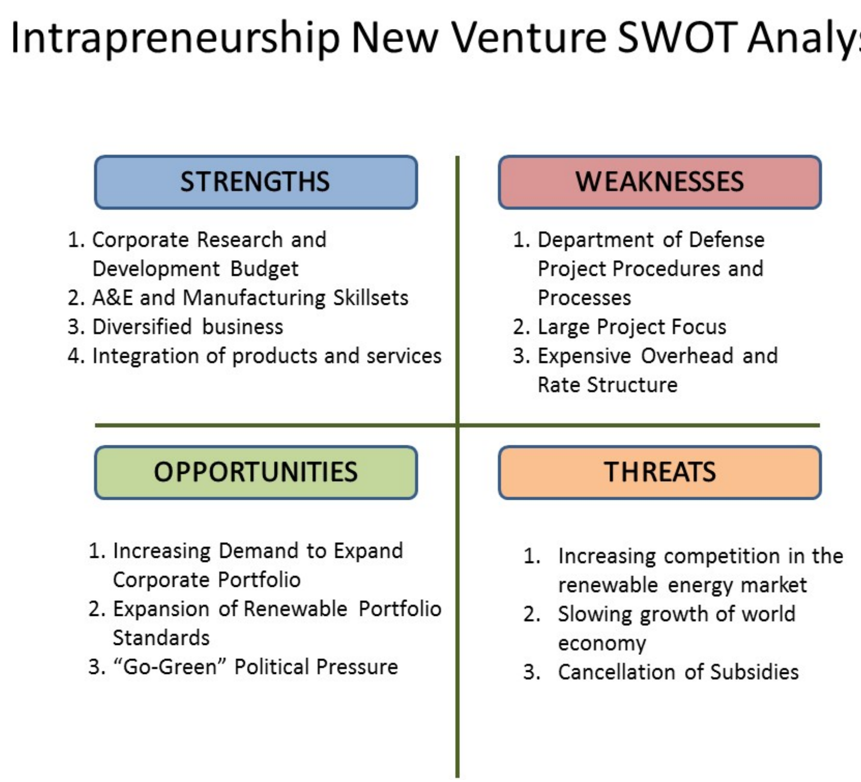


Figure 41. Intrapreneurship New Venture SWOT Analysis.

Strengths:

1. **Corporate Research and Development Budget.** The Corporation recognizes the need for continuous research and development and provides a yearly budget for R&D activities. In addition, the policies and procedures in place to request R&D funding allow for expanded opportunities as long as they are appropriately justified. Many corporations that just provide services do not have the capability of research and development since they exclusively rely on customer funding from services contracts and projects.
2. **A&E and Manufacturing Skillsets.** Since the corporation provides architectural and engineering services as well as systems integration, subcontracts and manufacturing services, there exists an abundance of skillsets that are available to assist in the new venture. Having diverse backgrounds from engineering, manufacturing, program management, subcontracts, etc. allows the project team to obtain full spectrum inputs throughout the project life cycle from inception thru execution. Having manufacturing inputs during the early design phases allows the projects to implement a manufacturing and production perspective for potential solutions to multiple customers.
3. **Diversified business.** The Corporation has many business segments including Defense, Commercial, and Services. The Corporation is also geographically diversified domestically and internationally. Geographical diversification provides advantages to knowledge of local policies, jurisdictions and procedures whereas business diversification provides advantages to the various types of contracts and customer basis.
4. **Integration of Products and Services.** The Corporation has focus on integrating the people, processes, and systems to increase collaboration and realize efficiency gains through the effective use of enterprise shared services and streamlined policies. The integration of corporate products and services should act as a catalyst to new venture start-ups due to increased collaboration and efficiency gains.

Weaknesses:

1. **Department of Defense Corporate Culture.** Because the majority of the Corporation's projects have been large Department of Defense (DOD) Contracts, the Corporation's culture, policies and procedures

have been structured around DOD policies, procedures and culture. In executing such projects throughout the history of the Corporation, most of the core staff, including engineers, program managers, financial analysts, etc., have built their careers based on DOD projects and experiences. Diversifying the corporate portfolio to include contracts other than from the Department of Defense, will include shifting the corporate culture from a DOD standards to a more competitive and stream-lined commercial culture. The weakness is the corporate comfort zone with a DOD culture that would deter the competitiveness of a commercial project initiative.

2. **Large project focus.** As with the DOD corporate culture, the mainstay of the corporation has been large, long-term projects. New ventures require quick, accurate, and stream-lined engineering and design processes with optimum staffing to implement projects while providing the Corporation with a competitive advantage. The “norm” will be small, fast-paced engineering solutions with a core team of discipline experts as opposed to the layers of manpower typical within a DOD structure.

3. **Expensive overhead and rate structure.** To be competitive while providing customer solutions, a modified rate structure will need to be developed as the rate structures typical for DOD projects will not be marketable. Modifying rate structures will need to be approved at a senior leadership level within the Corporation and will involve Human Resources, business sector leaders and senior managers. Considerations may also include a new venture sub division with a different compensation and benefit structure which could cause internal conflict between new ventures employees and mainstream corporate employees.

Opportunities:

1. **Increased demand to expand the corporate portfolio.** With DOD budgets shrinking on an annual basis and government funding in various states of uncertainty, the Corporation has recognized and socialized the need to expand into non-traditional markets. As such, business strategies branching into commercial sectors and/or using a more commercialized approach for government solutions are being explored to both broaden the Corporation’s core businesses and streamlining traditional policies and procedures to become more competitive. Thus, the timing of a new venture is very opportunistic as it aligns with the current corporate business strategy of expanding the business portfolio.

2. **Expansion of Renewable Portfolio Standards.** With twenty-nine states and Washington, D.C. now having renewable portfolio standards (RPS) or alternative energy portfolio standards (AEPS) which require a certain percentage of a utility's power plant capacity or generation to come from renewable or alternative energy sources by a given date, a new venture providing a viable renewable energy solution aligns with state requirements.
3. **"Go-Green" Political Pressure.** Political pressure to "go-green" is now global as there exists a rising awareness that renewable energy and energy efficiency are critical for not only addressing climate change, but also creating new economic opportunities and for providing energy access to the billions of people still living without modern energy services (REN21, 2015).

Threats:

1. **Increasing competition in the renewable energy market.** The renewable energy market is lucrative and continues to grow. The possible profits attract many newcomers and startups and threaten to take market share from the Corporation.
2. **Slowing growth of world economy.** The Corporation's sales heavily depend on investments into a new venture during times of slow economy growth which can have in impact on existing sales, forecasts and investments.
3. **Cancellation of subsidies.** Subsidies greatly impact compensation for capital investment and, return on investment, payback period and as such, competition with non-renewable solutions. Cancelling subsidies currently offered on the federal and state levels could pose a crippling effect on the financial viability of integrated renewable energy solutions.

9.5 Using SWOT Analysis Results to Develop a Business Strategy

The order in which business strategists think about strengths, weaknesses, threats and opportunities may have an impact on the direction of the analysis. Michael Watkins of the "Harvard Business Review" says that focusing on threats and opportunities first helps lead to productive discussions about what is going on in the external environment rather than getting bogged down in abstract discussions about what a company is good at or bad at (Hamel, 2015).

The results of the SWOT analysis helps determine:

- Making the most of the strengths
- Mitigating the weaknesses
- Capitalize on opportunities
- Manage the threats

By focusing on threats and opportunities first, the threat analysis helps the new venture to strategize mitigate the threats that could be negative growth and success factors. In our analysis the threats of increasing competition in the renewable energy market and a slowing global economy will be mitigated by focusing on renewable energy solutions that are proven in theory but have not yet developed a pilot program. By using our strengths of having a corporate research and development budget, experience with integration of products and services as well as architectural and engineering and manufacturing expertise, our new venture is in the unique position to help develop pilot programs of new technologies. This virtually eliminates the threats from start-up companies and engineering and design firms since they typically do not have a R&D budget as they rely on customer funding for all services.

The new venture also monopolizes on the opportunities to expand the corporate portfolio while utilizing current "go-green" political pressures as well as expanding renewable portfolio standards.

To overcome weaknesses, the new venture will be managed by an experienced senior leader who is well networked within the corporation. The new venture will be measured by a streamlined set of policies and procedures that are tailored for the new venture market while still maintaining alignment within the corporation. Progress will be closely monitored based on defined milestones for the new venture and not based on the same financial merits of the new venture's core line of business.

9.5 Conclusion

No business is a sure thing, but much of the uncertainty can be resolved through analysis of three of its sources: the market, the operational model, and the financial model. *Market risk* is a result of many factors, including whether the market is large enough to support the business, whether the market is growing, what trends exist in the industry, how the competition is structured, and how distribution works. The issue of market size is also important in feasibility analysis (Ebben, 2005). The SWOT analysis captured these risks and the resulting business strategy provided the market focus.

Operational risk deals with whether the business can set up internally to deliver goods and services to customers effectively. Operational risk will also include logistical issues with delivery and returns and effective use of service staff. The new venture’s ability to execute internally and keep costs under control will be essential to business success.

Financial model risk refers to the risk that the new venture won't work due to the numbers. For any new venture, financial projections through modelling should be generated to understand where breakeven will occur and what will drive the business financially (Ebben, 2005).

CHAPTER 10: INTRAPRENEURSHIP NEW VENTURE

Figure 42 illustrates the intrapreneuring process once the new venture has been approved by corporate leadership.

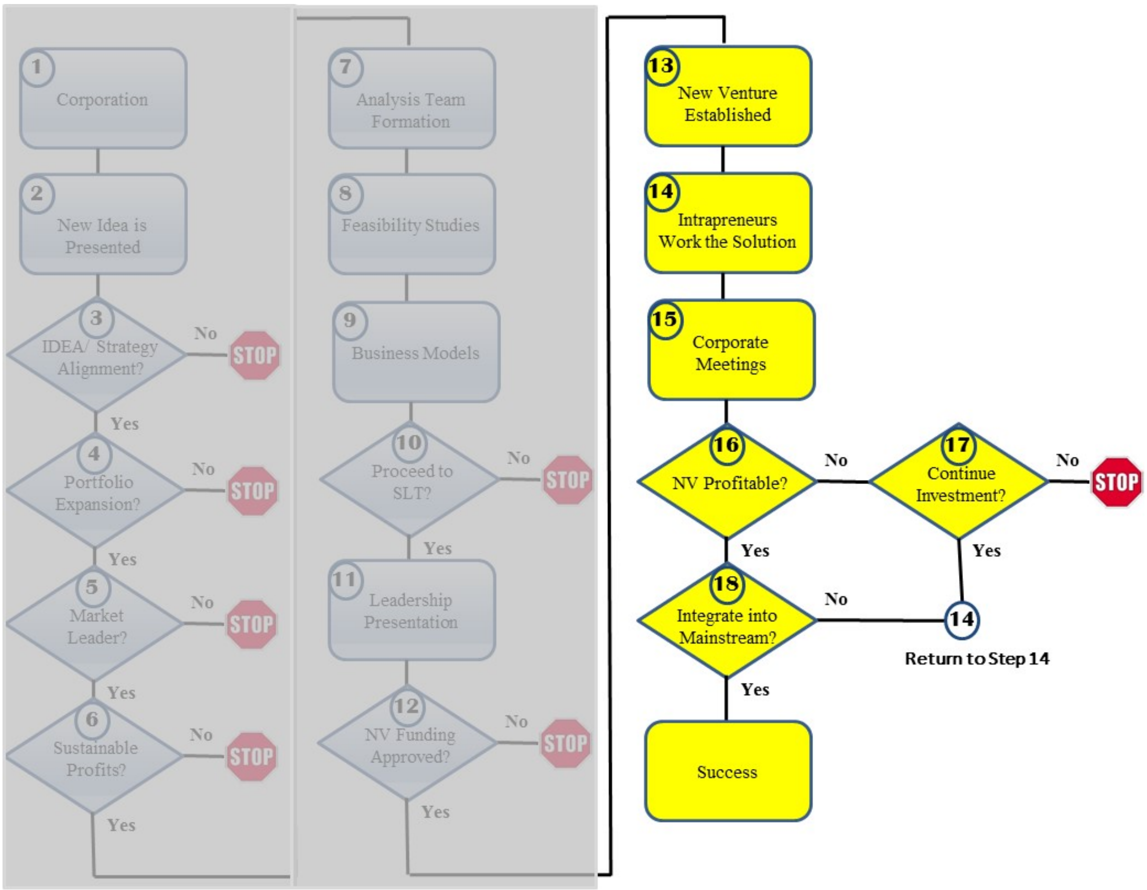


Figure 42. Intrapreneurship New Venture Process.

Once the new venture funding has been approved by the corporation, the new venture will be established with the group of intrapreneurs. While the new venture intrapreneural team work the solution (step 14) through design maturation, periodic meetings with corporate leadership (step 15) will occur to ensure progress and that the new venture team is receiving the proper funding, resources, guidance, and expertise are available for success. During these corporate meetings, senior leadership will assess new venture metrics and determine if the new venture is on a potential path to success or if unexpected circumstances warrant the new venture to be terminated (steps 16 and 17). The success of the new venture is based on long term goals not short term gains. As Wendell Weeks CEO of Corning stated, “We must recognize that the *greatest* value often comes from our longer-term bets." (Weeks, 2016). The design and solution maturation continue with the periodic corporate meetings until the new venture is profitable and worthy to become an integrated solution silo added to the corporate portfolio (step 18).

The Intrapreneurship New Venture Process is designed to work within all corporate frameworks. The size of the corporation is inconsequential to the process as the steps involving corporate decision gates will be tailored by the specific corporation implementing this process.

Future work to further develop the Intrapreneurship New Venture Process involves research incorporating multiple viable new ventures simultaneously while balancing corporate resources and expenditures.

Bibliography

1. Pinchot, Gifford (1985), *Intrapreneuring*. Harper and Row

2. Tarkahashi, Dean (September, 2000), Corporations are devising new ways to cultivate entrepreneurial efforts. And it's working. Retrieved from Reinventing the Intrapreneur: http://www.utdallas.edu/~chasteen/Reinventing%20the%20intrapreneur.htm

3. Duncan, Jack et. al (2001). Intrapreneurship and the Reinvention of the Corporation. Business Horizoins. May-June 1988

4. Kiff, Joe (January 2006), Transformational Leadership. Retrieved from: http://psychology.wikia.com/wiki/Transformational_leadership

5. Burns, James MacGregor (Jan 2004). Transforming Leadership. Grove Press

6. Babou, (Aug 2008). Transactional Leadership vs. Transformational Leadership. Retrieved from: http://leadershipchamps.wordpress.com/2008/08/04/transactional-leadership-vs-transformational-leadership/

7. Cashin, Jim (2000). *Transformational Leadership.* Retrieved from: http://www.mun.ca/educ/ed4361/virtual_academy/campus_a/aleader.html

8. Curphy, G., Ginnett, R. & Hughes, R. (2009). *Leadership: Enhancing the Lessons of Experience*. New York: McGraw-Hill

9. Tracey, J.B. (1998). Transformational leadership or effective managerial practices? Group and Organization Management, 23, 220-237

10. Johannsen, Murray, (1996). A Guide to Transformational Leadership. Retrieved from: http://www.legacee.com/Info/Leadership/LeadershipResouces.html

11. The Transformational Leadership Report (n.d.). Retrieved from transfomationalleadership.net: http://www.transformationalleadership.net/products/TransformationalLeadershipReport.pdf

12. Govindarajan, Vijay (2005). Building Breakthrough Businesses Within Established Organizations. Retrieved from: http://hbr.org/2005/05/building-breakthrough-businesses-within-established-organizations/ar/1

13. Friedman, Stephen, Sebenius, James (Jan/Feb 2009). Organizational Transformation" The Quiet Role of Coalition Leadership, Ivey Business Journal Online

14. Ritholtz, Barry, Task, Aaron (May 2009). Bailout Nation: How Greed and Easy Money Corrupted Wall Street and Shook the World Economy.

15. Levin, Carl, (April 2010), Senate Subcommittee Holds Fourth Hearing on Wall Street and the Financial Crisis: The Role of Investment Banks, Retrieved from http://levin.senate.gov/newsroom/release.cfm?id=324195

16. Sloan, Allan (2007), An Unsavory Slice of Subprime, The Washington Post, Retrieved from: http://www.washingtonpost.com/wp-dyn/content/article/2007/10/15/AR2007101501435.html?sid=ST2007101501858

17. Mack, Larry (2011), The Boeing-Vertol Era. Retrieved from: http://www.umcycling.com/boeingcars.html

18. Morrow, William (2011), Urban Mass Transportation Acts. Retrieved from: http://www.enotes.com/major-acts-congress/urban-mass-transportation-acts

19. Seamon, James (2000), Light Rail Notes. Retrieved from : http://thethirdrail.net/0007/lrt1.htm

20. American-rails.com (2011), The Massachusetts Bay Transportation Authority, The MBTA. Retrieved from: http://www.american-rails.com/massachusetts-bay-transportation-authority.html

21. Boeing (2011), History – Light Rail Vehicle/Rapid Transit Car. Retrieved from http://www.boeing.com/history/boeing/lightrail.html

22. Moore, Scott (1998). Boston's Green Line Crisis. Retrieved from: http://web.archive.org/web/20070222151636/members.aol.com/netransit/private/LRV.html

23. Pike, John (2011). Boeing Civil Aviation. Retrieved from: http://www.globalsecurity.org/military/systems/aircraft/civil-boeing.htm

24. Bauer, Eugene (1990). Boeing in Peace & War. TABA Publishing, Enumclaw, Washington

25. Sullivan, Kathleen (1998). Muni Knew About Trolley Lemons in '70s. Test Runs in Boston Found Major Trouble in Many Systems. Retrieved from: http://www.sfgate.com/cgi-bin/article.cgi?f=/e/a/1998/09/14/NEWS16054.dtl&ao=2

26. Rodgers, Eugene (1996). Flying High. The Story of Boeing and the Rise of the Jetliner Industry. The Atlantic Monthly Press, NY

27. Lampariello, Dan (2011). YAY History: MBTA LRVs. Retrieved from: http://bostontoat.blogspot.com/2011_06_01_archive.html

28. Leichuk, Ilene (2002). Muni Cars on a Roll Into City Junkyard / Even Preservationalists Reject the Clunkers. Retrieved from: http://articles.sfgate.com/2002-01-14/news/17526661_1_boeing-san-francisco-municipal-railway-san-francisco-s-system

29. Anderson, Edward (1996), Some Lessons from the History of Personal Rapid Transit (PRT). Retrieved from: http://advancedtransit.org/doc.aspx?id=1025

30. Gaffin, Adam (2003), Boston's Emerald Necklace. Retrieved from: http://www.boston-online.com/emerald.html

31. Boeing (2011), History: Thornton "T" A. Wilson. Retrieved from: http://www.boeing.com/history/boeing/wilson.html

32. Feldman, Jonahtan (2010), The Foundations for Extending Green Jobs: The Case of the Rail-Based Mass Transit Sector in North America. Retrieved from: http://search.proquest.com.ezproxy2.library.drexel.edu/docview/884976860

33. Babou, (Aug 2008). Transactional Leadership vs. Transformational Leadership. Retrieved from: http://leadershipchamps.wordpress.com/2008/08/04/transactional-leadership-vs-transformational-leadership/

34. Newhouse, John (2007). Boeing versus Airbus: The Inside Story of the Greatest International Competition in Business. Random House, NY

35. Vantuono, William (1996). Standardization: A New Approach – Standardization of Light Rail Vehicles. Retrieved from: http://findarticles.com/p/articles/mi_m1215/is_n10_v197/ai_18839000/?tag=content;col1

36. Dilger, Daniel (2008). San Francisco, Muni Fall Apart for MacWorld Expo. Retrieved from: http://www.roughlydrafted.com/2008/01/19/san-francisco-muni-fall-apart-for-macworld-expo/

37. Green Dividend (n.d.). Appendix One: Case Study of Boeing Vertol. Retrieved from: http://74.6.238.254/search/srpcache?ei=UTF-8&p=Boeing+Vertol+Light+Rail+Car+Venture&fr=my-myy&u=http://cc.bingj.com/cache.aspx?q=Boeing+Vertol+Light+Rail+Car+Venture&d=4504544841371439&mkt=en-US&setlang=en-US&w=ccb01108,e769484c&icp=1&.intl=us&sig=yc5uBQEoDw5Q0nw8N_DV_A--

38. Wiltshire Elizabeth (1979). Trolley Settlement to Aid Green Line. Retrieved from: http://www.thecrimson.com/article/1979/11/27/trolley-settlement-to-aid-green-line/

39. Visitask (2011). How to Perform a FMEA (Failure Modes and Effects Analysis)? Retrieved from: http://www.visitask.com/fmea.asp

40. Donnelly, Tom (n.d.). Devaluing the Concurrency. Retrieved from: http://www.defensestudies.org/cds/devaluing-the-concurrency/

41. Govindarajan, Vijay (2005). Building Breakthrough Businesses Within Established Organizations. Retrieved from: http://hbr.org/2005/05/building-breakthrough-businesses-within-established-organizations/ar/1

42. Friedman, Stephen, Sebenius, James (Jan/Feb 2009). Organizational Transformation" The Quiet Role of Coalition Leadership, Ivey Business Journal Online.

43. Ritholtz, Barry, Task, Aaron (May 2009). Bailout Nation: How Greed and Easy Money Corrupted Wall Street and Shook the World Economy.

44. Levin, Carl, (April 2010), Senate Subcommittee Holds Fourth Hearing on Wall Street and the Financial Crisis: The Role of Investment Banks, Retrieved from http://levin.senate.gov/newsroom/release.cfm?id=324195

45. Sloan, Allan (2007), An Unsavory Slice of Subprime, The Washington Post, Retrieved from: http://www.washingtonpost.com/wp-dyn/content/article/2007/10/15/AR2007101501435.html?sid=ST2007101501858

46. Nocera, Joe (2010), A Wall Street Invention Let the Crisis Mutate, New York Times, Retrieved from http://dealbook.nytimes.com/2010/04/19/a-wall-street-invention-let-the-crisis-mutate/?src=busln

47. Goldfarb, Zachary (2010), Goldman Sachs Executives Face Senators Investigating Role in Financial Crisis, Washington Post. Retrieved from: http://www.washingtonpost.com/wp-dyn/content/article/2010/04/27/AR2010042702326.html?sid=ST2010042705380

48. Deutschman, Alan (2005), Building a Better Skunk Works. Retrieved from: http://www.fastcompany.com/magazine/92/ibm.html

49. Antique Clocks Guy (2015). Bundy Manufacturing Company History. Retrieved from: http://www.clockguy.com/SiteRelated/SiteReferencePages/BundyManufacturingCompany.html

50. IBM (2015). IBM Archives. Bundy Manufacturing Company. Retrieved from : http://www-03.ibm.com/ibm/history/exhibits/vintage/vintage_4506VV2006.html

51. IBM (2015). IBM Archives. 1894. Retrieved from: http://www-03.ibm.com/ibm/history/history/year_1894.html

52. Madrigal, Alexis (2011). IBM's First 100 Years: A Heavily Illustrated Timeline. Retrieved from: http://www.theatlantic.com/technology/archive/2011/06/ibms-first-100-years-a-heavily-illustrated-timeline/240502/

53. Bellis, Mary (2015). IBM History: Profile of a Computer Manufacturing Giant. Retrieved from: http://inventors.about.com/od/computersandinternet/a/Ibm-History.htm

54. IBM (2015). Icons of Progress: IBM is Founded. Retrieved from: http://www-03.ibm.com/ibm/history/ibm100/us/en/icons/founded/

55. IBM (2015). IBM Archives. Chronological History of IBM. Retrieved from: http://www-03.ibm.com/ibm/history/history/decade_1900.html

56. Harreld, J. Bruce, O'Reilly III, Charles A, and Tushman, Michael (2006). Dynamic Capabilities at IBM: Driving Strategy into Action. Retrieved from: http://www.exed.hbs.edu/assets/Documents/dynamic-capabilities.pdf

57. O'Reilly III, Charles, Harreld, J. Bruce, and Tushman, Michael (2009). Organizational Ambidexterity" IBM and Emerging Business Opportunities. California Management Review Vol. 51. No. 4.

58. Nunes, Sharon (2004). IBM Research: Ultimate Source for New Businesses. Research Technology Management 0895-6308 04 55 00.

59. Baghai, Mehrdad, Coley, Stephen and White, David (2000). The Alchemy of Growth. Perseus Publishing, Cambridge, MA.

60. Wilkens, Jessica (2005). Business Strategy and Policy Case Discussion: EBOs at IBM. Retrieved from: http://www.academia.edu/13431982/Business_Strategy

61. Gerstner, Louis, Jr. (2002). Who Says Elephants Can't Dance? Harper Business ISBN: 0-06-052479-4

62. Wong, Albert (2008). Incubate New Business @ IBM. IBM Developer Works. Retrieved from: https://www.ibm.com/developerworks/community/blogs/PragmaticOpenComputing/entry/incubate_new_business_ibm?lang=en

63. Shah, Chintan, M., Zegveld, Marc A, and Roodhart, Leo (2008). Designing Ventures That Work. Research Technology Management. March-April, 2008, 0895-6308-08.

64. Shell (N.D.). Shell Game Changer. Retrieved from: http://www.shell.com/global/future-energy/innovation/innovate-with-shell/shell-gamechanger.html

65. Oakes, Chris (2003). Even after the bubble, Nokia venture arm keeps the faith. The New York Times. Retrieved from: http://www.nytimes.com/2003/11/24/business/worldbusiness/24iht-btnokia_ed3__0.html

66. USDA (2015). 2014 State Agriculture Overview North Dakota. Retrieved from: http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=NORTH%20DAKOTA

67. USDA (2015). 2014 State Agriculture Overview South Dakota. Retrieved from: http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=SOUTH DAKOTA

68. USDA (2015). 2014 State Agriculture Overview Montana. Retrieved from: http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=MONTANA

69. USDA (2015). 2014 State Agriculture Overview Wyoming. Retrieved from: http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=WYOMING

70. USDA (2015). 2014 State Agriculture Overview Nebraska. Retrieved from: http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=NEBRASKA

71. USDA (2015). 2014 State Agriculture Overview Colorado. Retrieved from: http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=COLORADO

72. USDA (2015). 2014 State Agriculture Overview Kansas. Retrieved from: http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=KANSAS

73. USDA (2015). 2014 State Agriculture Overview Oklahoma. Retrieved from: http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=OKLAHOMA

74. USDA (2015). 2014 State Agriculture Overview New Mexico. Retrieved from: http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=NEW%20MEXICO

75. USDA (2015). 2014 State Agriculture Overview Texas. Retrieved from: http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=TEXAS

76. Pennsylvania Public Utility Commission (2011). Electric Power Outlook for Pennsylvania 2010 – 2015. Page 2.

77. Global Energy Network Institute (2014). National Energy Grid. The United States of America. Retrieved from: http://www.geni.org/globalenergy/library/national_energy_grid/united-states-of-america/index.shtml

78. Prince, Andrew (2009). Visualizing the U.S. Electric Grid. Retrieved from: http://www.npr.org/templates/story/story.php?storyId=110997398

79. Tennyson, Kevin (2013). Energy Transmission is the United States. Retrieved from: http://teeic.anl.gov/er/transmission/restech/dist/index.cfm

80. Michaelson, John (2013). Getting More North Dakota Wind Power on the Grid. Public News Service – ND. February 2013. Retrieved from: http://www.publicnewsservice.org/index.php?/content/article/31008-1

81. Hauska, Charles (2007). Gas Utility Taps Into Farm Digester Biogas. BioCycle; Nov. 2007; 48,11; ProQuest pg. 57 – 60

82. U.S. Department of Energy (2013). North American Electric Reliability Corporation Interconnections.

83. Abraham, Spencer (2002). National Transmission Grid Study. US Department of Energy. May 2002.

84. The Energy Library (2009). North American Electricity Grid. Retrieved from: http://theenergylibrary.com/node/647

85. United States Department of Energy (2002). National Transmission Grid Study. May, 2002. Retrieved from: www.ferc.gov/industries/electric/gen-info/**transmission**-grid.pdf

86. Carey, John (2009). Wiring America Up to Green Power. Business Week 4154. November 9, 2009 pp 53-54.

87. Prince, Andrew et. a. (2009). Visualizing the U.S. Electric Grid. Retrieved from: http://www.npr.org/templates/story/story.php?storyId=110997398

88. United States Energy Information Agency (2009). U.S. Natural Gas Pipeline Network. Retreived from: http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/ngpipelines_map.html

88. National Renewable Energy Laboratory (2014). State and Local Governments. Retrieved from: http://www.nrel.gov/tech_deployment/state_local_governments/basics_portfolio_standards.html
89.
Beck, Fredric and Martinot, Eric (2004). Renewable Energy Policies and Barriers. Encyclopedia of Energy, Volume 5.

90. REN21 (2015). Renewable 2015 Global Status Report. Key Findings 2015. Renewable Energy Policy Network for the 21st Century. Retrieved from: www.ren21.net/status-of-renewables/global-status-report

91. Valentine, John, et. al. (2012). Food vs. fuel: the use of land for lignocellulosic 'next generation' energy crops that minimize competition with primary food production. GCB Bioenergy (2012) 4, 1–19, DOI: 10.1111/j.1757-1707.2011.01111.x

92. Harvey, Mark and Pilgrim, Sarah (2011). The new competition for land: Food, energy and climate change. Food Policy 36 (2011) S40-S51.

93. Alexandros, N, et. al. (2006). World Agriculture: Towards 2030/2050. Food and Agriculture Interim Report. Organization of the United Nations, FAO Rome. Retrieved from: http://www.fao.org/docrep/009/a0607e/a0607e00.htm

94. Tilman, David, et. al. (2002). Agriculture sustainability and intensive production practices. Nature. Volume 418 August 2002 pp. 671

95. DeFries, Ruth, Foley Jonathan and Asner, Gregory (2004). Land-Use Choices: Balancing Human Needs and Ecosystem Function. Frontiers in Ecology and the Environment, Vol. 2, No. 5 pp. 249-257.
96. Kimming, l, et. at. (2011). Biomass from agriculture in small-scale combined heat and power plants – A comparative life cycle assessment. Biomass and Bioenergy 35 (2011) 1572-1581.

97. Canals, Llorenc, et. al (2007). Key Elements in a Framework for Land Use Impact Assessment Within LCA. Int J LCA 12(1) 5 – 15 (2007).

98. Loiseau, Eleonore, et. al. (2013). Adapting the LCA framework to environmental assessment in land planning. Life Cycle Sustainability Assessment (2013) 18:1533-1548. DOI 10.1007/s11367-013-0588-y

99. Fthenakis, V. and Kim, H.C. (2009). Land use and electricity generation: A life-cycle analysis. Renewable and Sustainable Energy Reviews. Vol 13 pp. 1465 – 1474

100. US Department of Energy (2015). Renewable Portfolio Standard Policies. Retrieved from: http://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2014/11/Renewable-Portfolio-Standards.pdf

101. Richardson, Jake (2015). 50% Renewable Electricity Passed by California Senate. Clean Technica. Retrieved from: http://cleantechnica.com/2015/06/19/50-renewable-electricity-passed-california-senate/

102. Edwards, Joel, Othman, Maazuza, and Burn, Stewart (2015). A review of policy drivers and barriers for the use of anaerobic digestion in Europe, the United States and Australia. Renewable and Sustainable Energy Reviews 52 (2015) 815-828.

103. Leon (2013). The State of State Renewable Portfolio Standards. Clean Energy States Alliance. Retrieved from: www.cesa.org/assets/.../State-of-State-RPSs-Report-Final-June-2013.pdf

104. Centre for Climate and Energy Solutions (2014). Renewable and Alternative Energy Portfolio Standards. Retrieved from: http://www.c2es.org/us-states-regions/policy-maps/renewable-energy-standards

105. Wishart, David (2011). Wind Energy. Encyclopedia of the Great Plains. University of Nebraska, Lincoln. Retrieved from: http://plainshumanities.unl.edu/encyclopedia/doc/egp.ind.061

106. National Resources Defense Council (2014). Renewable Energy for America. Harvesting the Benefits of Homegrown Renewable Energy. Retrieved from: http://www.nrdc.org/energy/renewables/ndakota.asp

107. Gibbs, Holly et. al. (2008). Carbon Payback Times for Crop-Based Biofuel Expansion in the Tropics; the Effects of Changing Yield and Technology. Environmental Research Letters, Environ. Res. Lett. 3 (2008) 034001 (10pp). doi:10.1088/1748-9326/3/3/034001

108. Denholm, Paul et. al (2009). Land-Use Requirements of Modern Wind Power Plants in the United States. National Renewable Energy Laboratory (NREL) Technical Report NREL/TP-6A2-45834.

109. Martinez, E. et. al (2009). Life cycle assessment of a multi-megawatt wind turbine. Renewable Energy Vol. 34 no. 3 pp. 667-678.

110. Pimentel, David et. al. (2002). Renewable Energy: Current and Potential Issues. Bioscience; Dec 2002; 52, 12; ProQuest.

111. Berglund, Maria and Borjesson, Pal (2005). Assessment of energy performance in the life-cycle of biogas production. Biomass and Bioenergy 30 (2006) 254-266.

112. Cherubini, Francesco et. al. (2009). Energy-and greenhouse gas-based LCA of biofuel and bioenergy systems: Key issues, ranges and recommendations. Resources, Conservation and Recycling 53 (2009) 434-447.

113. Poschl, Martina et. al. (2010). Evaluation of energy efficiency of various biogas production and utilization pathways. Applied Energy 87 (2010) 3305-3321 DOI: 10.1016/j.apenergy.2010.05.011

114. US EPA (2013). Operating Anaerobic Digester Projects. AgSTAR. United States Environmental Protection Agency. Retrieved from: http://epa.gov/agstar/projects/index.html

115. Harvey, Mark and Pilgrim, Sarah (2011). The new competition for land: Food, energy and climate change. Food Policy 36 (2011) S40–S51.

116. ISO 14040: 2006. Environmental management – Life Cycle Assessment – Principles and Framework. International Organization of Standardization.

117. Gagnon, Luc et. al. (2002). Life-cycle assessment of electricity generation options: The status of research in year 2001. Energy Policy 30 (2002) 1267-1278.

118. Cherubini, Francesco and Stromman, Anders (2011). Life cycle assessment of bioenergy systems: State of the art and future challenges. Bioresource Technology 102 (2011) 437-451. DOI: 10.1016/j.biotech.2010.08.010.

119.Doka, Gabor et. al (2002). The Assessment of Environmental Impacts caused by Land Use in the Life Cycle Assessment of Forestry and Forest Products. Final Report of Working Group 2 "Land use" of COST Action E9. Retrieved from: www.doka.ch/COSTE9LandUseDoka.pdf

120.Tillman, Anne-Marie, et. al. (1993). Choice of System Boundaries in life cycle assessment. Technical Environmental Planning, Chalmers University of Technology. Journal of Cleaner Production. 1994 Volume 2 Number 1. pp, 21-29

121.United States Geological Survey (2014). USGS Map of Wind Farms in the United States. Retrieved from: http://eerscmap.usgs.gov/windfarm/

122.United States Environmental Protection Agency (2014). AgSTAR Map of Anaerobic Digester Projects. Retrieved from: http://gispub4.epa.gov/AgSTAR/index.html

123.United Stated Department of Energy (2014). 2013 Wind Technologies Market Report. Retrieved from: http://www.energy.gov/sites/prod/files/2014/08/f18/2013%20Wind%20Technologies%20Market%20Report_1.pdf

124.Otter Trail Power Company (2014). Rates and Pricing. Retrieved from: https://www.otpco.com/rates-and-pricing/#competitive-rates

125.DSIRE (2014). Database of State Incentives for Renewables & Efficiency. North Dakota. North Carolina Clean Energy Technology Center at North Carolina State University. Retrieved from: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ND04R

126.USDA (2014). USDA Agriculture Resource Management Survey. Milk Cost-of-Production Estimates – 2010 Base Monthly. Retrieved from: www.ers.usda.gov/datafiles/Milk_Cost_of_Production

127.DSIRE (2014). Database of State Incentives for Renewables & Efficiency. Minnesota. Retrieved from: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=MN14R

128.Alexander, Ron (2012). Digestate Utilization in the U.S. Biocycle January 2012, Vol. 53, No. 1, p. 56

129.USDA (2014). National Agricultural Statistic Service. National Statistics for Milk. Retrieved from: http://www.nass.usda.gov/Statistics_by_Subject/result.php?4B229587-F308-34B9-8E3F-A02380B426BD&sector=ANIMALS%20%26%20PRODUCTS&group=DAIRY&comm=MILK

130.US Energy Information Administration (2012). U.S. Wind Capacity Factors – 2012 (Preliminary). Form EIA-923. Retrieved from: https://www.wind-watch.org/documents/u-s-wind-capacity-factors-2012-preliminary/print/

131.Myhre, Gunnar and Shindell, Drew (2013). Anthropogenic and Natural Radiative Forcing. Intergovernmental Panel on Climate Change (IPCC). Retrieved from: https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf

132. Centre for Climate and Energy Solutions (2015). Anaerobic Digesters. Retrieved from: http://www.c2es.org/technology/factsheet/anaerobic-digesters

133.Global Methane Initiative (2013). Successful Applications of Anaerobic Digestion from Across the World. Retrieved from: https://www.globalmethane.org/documents/GMI%20Benefits%20Report.pdf

134.Tonneson, Lon (2007). Dairy uses its manure to generate electricity. Dakota Farmer Volume 125 No. 12. Retrieved from: http://magissues.farmprogress.com/DFM/DK12Dec07/dfm007.pdf

135. Lang, Chris (2013). How much does a carbon credit cost? "There is no such thing as a generic price". Retieved from: http://redd-monitor.org/2013/01/22/how-much-does-a-carbon-credit-cost.

136. Dairy Farming Today (2014). State Statistics. Retrieved from: http://www.dairyfarmingtoday.org/Learn-More/FactsandFigures/Pages/StateStatistics.aspx

137. Institute for Energy Research (2014). South Dakota. Retrieved from: http://instituteforenergyresearch.org/states/south-dakota/

138. National Renewable Energy Laboratory (2010). Renewable Energy Project Finance. CREST Cost of Energy Models. Retrieved from: https://financere.nrel.gov/finance/content/crest-model

139. DSIRE (2014). Database of State Incentives for Renewables & Efficiency. South Dakota. Retrieved from: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=SD02R

140. United States Environmental Information Association (2014). South Dakota State Profile and Energy Estimates. Retrieved from: http://www.eia.gov/state/?sid=sd

141. University of South Dakota (2007). Management Guide for Biomass Feedstock Production from Switchgrass in Northern Great Plains. Sun Grant Initiative, North Central Center.

142. Esri, HERE, Delorne, TomTom, Increment P Corp, GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, OpenStreetMap contributors, and the GIS User Community (2014)._.

143. American Wind Energy Association (2013). North Dakota State Wind Energy Facts. Retrieved from: http://www.awea.org/resources/statefactsheets.aspx?itemnumber=890

144. Farm Journal (2015). Drop in North Dakota Dairy Farms Discouraging to Many. Retrieved from: http://www.agweb.com/article/drop-in-north-dakota-dairy-farms-discouraging-to-many-NAA-associated-press/

145. Heinrich, Sarah (2012). Dairy Industry Struggles. Retrieved from: http://www.kxnet.com/story/20396903/dairy-industry-struggles

146. Lazarus, William and Rudstrom, Margaretha (2007). The Economics of Anaerobic Digester Operation on a Minnesota Dairy Farm. Review of Agricultural Economics. Volume 29, Number 2. DOI: 10.1111/j.1467-9353.2007.00347.x

147. Associated Press (2015). Legislature considers exempting dairy, hog farms from North Dakota anti-corporate farming laws. Retrieved from: http://www.foxbusiness.com/markets/2015/02/13/legislature-considers-exempting-dairy-hog-farms-from-north-dakota-anti/

148. USDA (2014). US Monthly dairy costs of production per cwt or milk. Retrieved from: www.ers.usda.gov/datafiles/Milk_Cost_of_Production

149. Wisler, Alice (2015). How to Measure and Price Carbon Credits. Retrieved from: http://greenliving.lovetoknow.com/How_to_Measure_and_Price_Carbon_Credits

150. AgriNews (2015). North Dakota dairy farms disappear. Retrieved from: http://www.agrinews-pubs.com/Content/News/Markets/Article/North-Dakota-dairy-farms-disappear-/8/26/12097

151. Krom, Larry (2008). Opportunities in Manure Management and Renewable Energy. Public Service Commission of Wisconsin Focus on Energy Program. Retrieved from: http://fyi.uwex.edu/midwestmanure/files/2009/10/11-Krom-Farm-Digesters-v5_2.pdf

152. Goodrich, Philip (2005). Anaerobic Digester Systems for Mid Sized Dairy Farms. The Minnesota Project. Retrieved from: http://www.mnproject.org/pdf/agstar%20report%20full%20update.pdf

153. US Energy Information Administration (2015). Levelized Cost and Levelized Avoided Cost or New Generation Resources in the Annual Energy Outlook 2015. Retrieved from: http://www.eia.gov/forecasts/aeo/electricity_generation.cfm

154. US Energy Information Administration (2014). North Dakota State Profile and Energy Estimates. Retrieved from: http://www.eia.gov/state/?sid=ND

155. National Resources Defense Council (2014). Renewable Energy for America. Harvesting the Benefits of Homegrown Renewable Energy. Retrieved from: http://www.nrdc.org/energy/renewables/ndakota.asp

156.
NRECA. (2015). Cooperatives and Renewable Resources. Retrived from: http://www.nreca.coop/wp-content/plugins/nreca-interactive-maps/RenewableEnergy/index.html

157. US Department of Energy (2015). Renewable Portfolio Standard Policies. Retrieved from: http://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2014/11/Renewable-Portfolio-Standards.pdf

158. Centre for Climate and Energy Solutions (2014). Renewable and Alternative Energy Portfolio Standards. Retrieved from: http://www.c2es.org/us-states-regions/policy-maps/renewable-energy-standards

159. US Department of Energy (2015). Energy Storage. Office of Electricity Delivery & Energy Reliability. Retrieved from: http://energy.gov/oe/services/technology-development/energy-storage

160. Caplinger, Dan (2012), "Profit from Companies that Reinvent Themselves"[Online]. Available: http://www.fool.com/retirement/general/2012/11/12/profit-from-companies-that-reinvent-themselves.aspx.

161. New Deal (2015). TVA: Electricity for All. Retrieved from : http://newdeal.feri.org/tva/tva10.htm

162. Bartlett Electric Cooperatives (2015). Bartlett Electric Cooperative. Retrieved from: http://bartlettec.coop/

163. Columbia Encyclopedia (2014). Rural Electrification Administration. 6th ed. Retrieved from: http://www.encyclopedia.com/topic/Rural_Electrification_Administration.aspx

164. NRECA (2014). History of Electric Co-ops. Retrieved from: http://www.nreca.coop/about-electric-cooperatives/history-of-electric-co-ops/

165. Hallgran, Lennart (2009). Baltic Biogas Bus. Retrieved from: http://www.balticbiogasbus.eu/web/

166. United States Department of Agriculture (USDA) Economic Research Service (2013). Milk cows and production by State and region (Annual). Retrieved from: http://www.ers.usda.gov/data-products/dairy-data.aspx

167. Abraham, Spencer. (2002). *National Transmission Grid Study*: 2002. Retrieved from Energy.gov: http://energy.gov/oe/downloads/national-transmission-grid-study-2002.

168. DeBruyn, Jake. (2012). *Anaerobic Digestion Basics.* Retrieved from Ontario Ministry of Agriculture and Food: http://www.omafra.gov.on.ca/english/engineer/facts/07-057.htm

169. US EPA (2013). Operating Anaerobic Digester Projects. AgSTAR. United States Environmental Protection Agency. Retrieved from: http://epa.gov/agstar/projects/index.html

170. Pela Flow Consulting (N.D.). The Windpower Program. "Wind turbine power output variation with steady windspeed. Retrieved from: http://www.wind-power-program.com/turbine_characteristics.htm

171. National Wind Watch (N.D.). FAQ-Output. Retrieved from: http://www.wind-watch.org/faq-output.php

172. AGWeb (2015). Drop in North Dakota Dairy Farms Discouraging to Many. Retrieved from: http://www.agweb.com/article/drop-in-north-dakota-dairy-farms-discouraging-to-many-NAA-associated-press/

173. Goodrich, Philip (2005). Anaerobic Digester Systems for Mid-Sized Dairy Farms. The Minnesota Project. AgStar fund for rural America. Retrieved from: http://www.mnproject.org/pdf/agstar%20report%20full%20update.pdf

174. Cooper, Brittany (2012). Nation's Largest Manure-Based Anaerobic Digester in Lincoln County. KMTV.com news. Retrieved from: http://www.kmvt.com/news/local/Nations-Largest-Manure-Based-Anerobic-Digester-In-Lincoln-County-148392585.html

175. Renewable Energy Concepts (N.D.). Submersible Mixers. Retrieved from: http://www.renewable-energy-concepts.com/biomass-bioenergy/anaerobic-methane-digester/mixing-mixer-agitator/submersible-mixers.html

176. Sustainable Conservation (2014). Cow Power. Transforming Green House Gases to Renewable Energy. Chapter 2 p. 46.

177. D&D Machine & Hydraulics (2014). Digester Pump. Retrieved from: http://www.ddpumps.com/digest-pump.php

178. Electrigaz Technologies (2008). Feasibility Study – Biogas upgrading and grid injection in the Fraser Valley, British Columbia. Retrieved from: www.biogasupgrading.com/FS_en.htm

179. TheCattle Site (2014). Saving Electricity in the Dairy. Retrieved from: http://www.thecattlesite.com/articles/1903/saving-electricity-in-the-dairy/

180. US Energy Information Administration (2012). U.S. Wind Capacity Factors – 2012 (Preliminary). Form EIA-923. Retrieved from: https://www.wind-watch.org/documents/u-s-wind-capacity-factors-2012-preliminary/print/

181. Fingersh, L et. al. (2006). Wind Turbine Design Cost and Scaling Model. National Renewable Energy Laboratory (NREL) Technical Report NREL/TP-500-40566.

182. eXtension (2014). Economics of Anaerobic Digesters for Processing Animal Manure. Retrieved from: https://www.extension.org/pages/19461/economics-of-anaerobic-digesters-for-processing-animal-manure

183. Bennett, David (2011). REAP grants reduce upgrade costs for Arkansas producers. Retrieved from: http://deltafarmpress.com/government/reap-grants-reduce-upgrade-costs-arkansas-producers

184. U.S. Energy Information Administration (2012). Natural Gas Prices. Retrieved from: http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_snd_m.htm

185. U.S. Energy Information Administration (2012). Electric Power Monthly. Retrieved from: http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a

186. Wisler, Alice (2015). How to Measure and Price Carbon Credits. Retrieved from: http://greenliving.lovetoknow.com/How_to_Measure_and_Price_Carbon_Credits

187. Lang, Chris (2013). Responses from Paul Seakens, Director of Carbon Neutral Investments and Enviro Associates. Retrieved from: http://www.redd-monitor.org/2012/12/08/response-from-paul-seakens-director-of-carbon-neutral-investments-and-enviro-associates/

188. Otter Trail Power Company (2014). Rates and Pricing. Retrieved from: https://www.otpco.com/rates-and-pricing/#competitive-rates

189. Goodrich, Ryan (2015). SWOT Analysis: Examples, Templates & Definition. Business News Daily. Retrieved from: http://www.businessnewsdaily.com/4245-swot-analysis.html

190. Jurevicius, Ovidijus (2013). SWOT Analysis – Do It Properly! Strategic Management Insight. Retrieved from: http://www.strategicmanagementinsight.com/tools/swot-analysis-how-to-do-it.html

191. REN21 (2015). Renewables 2015 Global Status Report. Key Findings 2015. Renewable Energy Policy Network for the 21st Century.

192. Hamel, Gregory (2015). Difference Between SWOT & TOWS Analysis. Hearst Newspapers, LLC. Retrieved from: http://smallbusiness.chron.com/difference-between-swot-tows-analysis-23169.html

193. Ebben, Jay (2005). Managing Risk in a New Venture. Retrieved from: http://www.inc.com/resources/startup/articles/20050301/risk.html

194. Weeks, Wendell (2016). Creating Value from Long-Term Bets. McKinsley Quarterly. Retrieved from: http://www.mckinsey.com/insights/leadership/creating_value_from_long_term_bets?cid=other-soc-twi-mkq-mck-oth-1602&kui=KgpbdquGVTFfAu5q75EPNA

Appendix A Tabulated Wind Farm Data by State (Denholme, 2009)

Table 19. Tabulated Wind Farm Data by State (Denholme, 2009).

Name	State	No. Of Turbines	Capacity MW	Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW
Bluegrass Ridge	MO	27	57	2835.0.	50
Conception Wind Farm	MO	24	50	2835.0.	56.25
Cow Brance	MO	24	50	2835.0.	56.25
Langdon Wind	ND	106	159	12312	77.34
North Dakota Wind	ND	41	62	1215	19.76
Tatanka Wind Farm	ND	120	180	5702.4	31.68
Wilton Wind Energy	ND	33	50	3240	65.45
Ashtabula Wind Center II	ND	133	200	19958.4	99.79
MinnDakota Wind Farm II	SD	36	54	1608.1	29.78
South Dakota Wind Energy	SD	27	41	1012.5	25
Wessington Springs	SD	66	99	2430	24.55
White Wind Farm	SD	103	200	7257.6	36.29
Buffalo Ridge Wind Farm	SD	204	306	20032.5	65.47
Foote Creek 1	WY	69	41	846.5	20.45
Glenrock Wind Energy	WY	66	99	5670	57.27
Seven Mile Hill	WY	66	99	4050	40.91
Ainsworth Wind Energy	NE	36	59	4455	75
Elkhorn Ridge	NE	27	80	3383.8	42.35
Cedar Creek Wind Farm	CO	274	300	15390	51.3
Cedar Point	CO	150	300	8100	27
Colorado Green	CO	108	162	4795.2	29.6
Spring Canyon	CO	87	130	8931.9	68.71
Twin Buttes Wind Power	CO	50	75	3645	48.6
Central Plains Wind Farm	KS	33	99	2430	24.55
Elk River	KS	100	150	3202.3	21.35
Flat Ridge Wind Farm	KS	40	100	2025	20.25
Gray County Wind Farm	KS	170	112	2430	21.7
Meridian Way Wind Farm	KS	79	201	8100	40.3
Smoky Hills Wind Farm 1	KS	56	101	4050	40.18
Spearville	KS	67	101	2025	20.15
Smoky Hills Wind Farm II	KS	99	1449	5670	38.18
Blue Canyon Wind Power	OK	129	225	6480	28.74
OK Wind Energy Center A	OK	68	102	486	4.76
Weatherford Wind	OK	98	147	2106	14.33
Red Hills Wind Farm	OK	82	123	2025	16.46
Aragonne Wind LLC	NM	90	90	3888	43.2
New Mexico Wind	NM	136	204	3888	19.06
San Juan Mesa	NM	120	120	1749.6	14.58

Table 19 (continued)

Brazos Wind Ranch	TX	160	160	7776	48.6
Callahan Divide	TX	76	114	2430	21.32
Champion Wind Farm	TX	55	127	5670	44.82
Desret Sky	TX	107	161	3888	24.22
Elbow Creek Wind	TX	53	122	2713.5	22.26
Forest Creek Wind	TX	54	124	6075	48.91
Goat Mountain Wind Ranch	TX	109	150	4252.5	28.35
Horse Hollow Wind Energy Center	TX	419	733	19035	25.99
King Mountain I & II	TX	214	278	6075	21.84
Liano Estacado Wind Ranch	TX	80	80	2332.8	29.16
Lone Star Phase I	TX	200	400	8100	20.25
Lone Star Phase II	TX	100	200	15460.9	77.3
Penascal Wind Farm	TX	87	202	6075	30.07
Red Canyon Wind Energy	TX	56	84	3847.5	45.8
Roscoe Wind Farm	TX	627	782	28350	36.28
Sherbino I Wind Farm	TX	50	150	4050	27
Silver Star I Wind Farm	TX	24	60	3057.8	50.96
Stanton Wind Farm	TX	80	120	6885	57.38
Sweetwater Phase IV - Mistsubishi Portion	TX	135	135	4860	36
Sweetwater Phase IV - Siemens Portion	TX	46	106	4860	45.94
Trent Mesa	TX	100	150	3628.8	24.19
Wildorado Wind Ranch	TX	70	161	6480	40.25
Woodward Mountain I & II	TX	242	160	3785.1	23.66
Bull Creek Wind Farm	TX	180	180	24300	135
Panther Creek Wind Farm	TX	111	167	9315	55.95
Wolf Ridge Wind Farm	TX	75	113	4131	36.72
Ocotillo	TX	28	59	1012.5	17.22
Gulf Winds Project	TX	118	283	3179.7	11.23

Appendix B North Dakota Agriculture Overview (USDA, 2015)

2014 STATE AGRICULTURE OVERVIEW

North Dakota

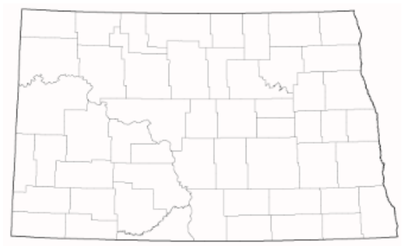
† Survey Data from Quick Stats as of: Nov/08/2015

Farms Operations †

Farm Operations - Area Operated, Measured in Acres / Operation	1,297
Farm Operations - Number of Operations	30,300
Farm Operations - Acres Operated	39,300,000

Livestock Inventory †

Cattle, Cows, Beef - Inventory (First of Jan. 2015)	904,000
Cattle, Cows, Milk - Inventory (First of Jan. 2015)	16,000
Cattle, Incl Calves - Inventory (First of Jan. 2015)	1,650,000
Cattle, On Feed - Inventory (First of Jan. 2015)	44,000
Sheep, Incl Lambs - Inventory (First of Jan. 2015)	64,000
Hogs - Inventory (First of Dec. 2014)	138,000



Milk Production †

Milk - Production, Measured in Lb / Head	20,250
Milk - Production, Measured in $	76,464,000
Milk - Production, Measured in Lb	324,000,000

Figure 43. North Dakota Agriculture Overview (USDA, 2015).

Table 20. North Dakota 2012 Ranked Items Within the US Census State Profile (USDA, 2015).

Item	Quantity	U.S. Rank
TOP CROP ITEMS (acres)		
Wheat for grain, all	7,767,484	2
Spring wheat for grain	5,708,405	1
Soybeans for beans	4,729,137	7
Corn for grain	3,465,997	9
Forage-land used for all hay and haylage, grass silage, and greenchop	2,172,738	9
TOP LIVESTOCK INVENTORY ITEMS (number)		
Cattle and calves	1,809,613	16
Turkeys	419,319	19
Colonies of bees	370,480	2
Hogs and pigs	133,653	27
Layers	92,754	45

Appendix C South Dakota Agriculture Overview (USDA, 2015)

2014 STATE AGRICULTURE OVERVIEW

South Dakota

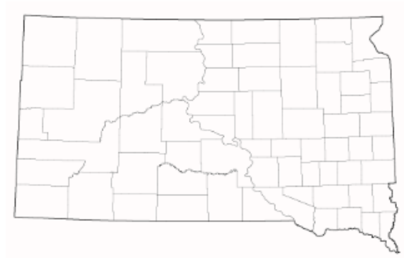
† Survey Data from Quick Stats as of: Nov/09/2015

Farms Operations †

Farm Operations - Area Operated, Measured in Acres / Operation	1,366
Farm Operations - Number of Operations	31,700
Farm Operations - Acres Operated	43,300,000

Livestock Inventory †

Cattle, Cows, Beef - Inventory (First of Jan. 2015)	1,632,000
Cattle, Cows, Milk - Inventory (First of Jan. 2015)	98,000
Cattle, Incl Calves - Inventory (First of Jan. 2015)	3,700,000
Cattle, On Feed - Inventory (First of Jan. 2015)	385,000
Sheep, Incl Lambs - Inventory (First of Jan. 2015)	255,000
Hogs - Inventory (First of Dec. 2014)	1,270,000
Turkeys - Production, Measured in Head	4,500,000



Milk Production †

Milk - Production, Measured in Lb / Head	21,742
Milk - Production, Measured in $	520,923,000
Milk - Production, Measured in Lb	2,109,000,000

Figure 44. South Dakota Agriculture Overview (USDA, 2015).

Table 21. South Dakota 2012 Ranked Items Within the US Census State Profile (USDA, 2015).

Item	Quantity	U.S. Rank
TOP CROP ITEMS (acres)		
Corn for grain	5,289,110	6
Soybeans for beans	4,714,204	8
Forage-land used for all hay and haylage, grass silage, and greenchop	2,615,189	4
Wheat for grain, all	2,203,785	6
Winter wheat for grain	1,208,309	8
TOP LIVESTOCK INVENTORY ITEMS (number)		
Cattle and calves	3,893,251	7
Layers	2,450,780	29
Turkeys	2,449,784	13
Hogs and pigs	1,191,162	11
Pullets for laying flock replacement	(D)	30

Appendix D Montana Agriculture Overview (USDA, 2015)

2014 STATE AGRICULTURE OVERVIEW

Montana

† Survey Data from Quick Stats as of: Nov/09/2015

Farms Operations †

Farm Operations - Area Operated, Measured in Acres / Operation	2,147
Farm Operations - Number of Operations	27,800
Farm Operations - Acres Operated	59,700,000

Livestock Inventory †

Cattle, Cows, Beef - Inventory (First of Jan. 2015)	1,506,000
Cattle, Cows, Milk - Inventory (First of Jan. 2015)	14,000
Cattle, Incl Calves - Inventory (First of Jan. 2015)	2,500,000
Cattle, On Feed - Inventory (First of Jan. 2015)	40,000
Sheep, Incl Lambs - Inventory (First of Jan. 2015)	215,000
Hogs - Inventory (First of Dec. 2014)	176,000

Milk Production †

Milk - Production, Measured in Lb / Head	21,500
Milk - Production, Measured in $	66,220,000
Milk - Production, Measured in Lb	301,000,000

Figure 45. Montana Agriculture Overview (USDA, 2015).

Table 22. Montana 2012 Ranked Items Within the US Census State Profile (USDA, 2015).

Item	Quantity	U.S. Rank
TOP CROP ITEMS (acres)		
Wheat for grain, all	5,627,463	3
Spring wheat for grain	2,909,910	2
Forage-land used for all hay and haylage, grass silage, and greenchop	2,267,198	8
Winter wheat for grain	2,168,021	4
Barley for grain	778,521	2
TOP LIVESTOCK INVENTORY ITEMS (number)		
Cattle and calves	2,633,740	10
Layers	464,802	40
Sheep and lambs	236,646	7
Pullets for laying flock replacement	225,021	38
Hogs and pigs	173,953	22

Appendix E Wyoming Agriculture Overview (USDA, 2015)

2014 STATE AGRICULTURE OVERVIEW

Wyoming

† Survey Data from Quick Stats as of: Nov/09/2015

Farms Operations †

Farm Operations - Area Operated, Measured in Acres / Operation	2,598
Farm Operations - Number of Operations	11,700
Farm Operations - Acres Operated	30,400,000

Livestock Inventory †

Cattle, Cows, Beef - Inventory (First of Jan. 2015)	694,000
Cattle, Cows, Milk - Inventory (First of Jan. 2015)	6,000
Cattle, Incl Calves - Inventory (First of Jan. 2015)	1,300,000
Cattle, On Feed - Inventory (First of Jan. 2015)	75,000
Sheep, Incl Lambs - Inventory (First of Jan. 2015)	345,000
Hogs - Inventory (First of Dec. 2014)	83,000

Milk Production †

Milk - Production, Measured in Lb / Head	21,583
Milk - Production, Measured in $	30,303,000
Milk - Production, Measured in Lb	129,500,000

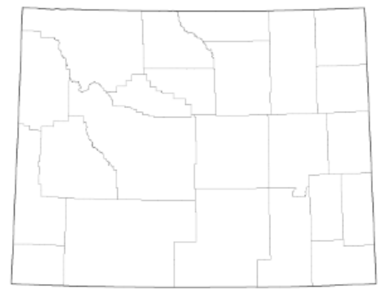


Figure 46. Wyoming Agriculture Overview (USDA, 2015).

Table 23. Wyoming 2012 Ranked Items Within the US Census State Profile (USDA, 2015).

Item	Quantity	U.S. Rank
TOP CROP ITEMS (acres)		
Forage-land used for all hay and haylage, grass silage, and greenchop	1,053,646	22
Wheat for grain, all	131,905	33
Winter wheat for grain	120,113	32
Barley for grain	62,590	7
Corn for grain	60,349	35
TOP LIVESTOCK INVENTORY ITEMS (number)		
Cattle and calves	1,307,731	23
Sheep and lambs	354,785	4
Hogs and pigs	85,432	30
Horses and ponies	72,461	19
Colonies of bees	45,029	16

Appendix F Nebraska Agriculture Overview (USDA, 2015)

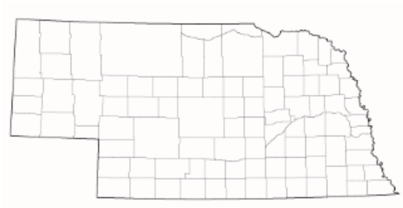
2014 STATE AGRICULTURE OVERVIEW

Nebraska

† Survey Data from Quick Stats as of: Nov/09/2015

Farms Operations †

Farm Operations - Area Operated, Measured in Acres / Operation	921
Farm Operations - Number of Operations	49,100
Farm Operations - Acres Operated	45,200,000



Livestock Inventory †

Cattle, Cows, Beef - Inventory (First of Jan. 2015)	1,786,000
Cattle, Cows, Milk - Inventory (First of Jan. 2015)	54,000
Cattle, Incl Calves - Inventory (First of Jan. 2015)	6,300,000
Cattle, On Feed - Inventory (First of Jan. 2015)	2,530,000
Goats, Meat & Other - Inventory (First of Jan. 2015)	(NA)
Goats, Milk - Inventory (First of Jan. 2015)	3,700
Sheep, Incl Lambs - Inventory (First of Jan. 2015)	81,000
Hogs - Inventory (First of Dec. 2014)	3,200,000

Milk Production †

Milk - Production, Measured in Lb / Head	22,130
Milk - Production, Measured in $	298,750,000
Milk - Production, Measured in Lb	1,195,000,000

Figure 47. Nebraska Agriculture Overview (USDA, 2015).

Table 24. Nebraska 2012 Ranked Items Within the US Census State Profile (USDA, 2015).

Item	Quantity	U.S. Rank
TOP CROP ITEMS (acres)		
Corn for grain	9,087,851	3
Soybeans for beans	4,983,253	6
Forage-land used for all hay and haylage, grass silage, and greenchop	2,487,312	5
Wheat for grain, all	1,309,269	10
Winter wheat for grain	1,302,674	7
TOP LIVESTOCK INVENTORY ITEMS (number)		
Layers	9,351,688	14
Cattle and calves	6,385,675	2
Hogs and pigs	2,992,576	6
Pullets for laying flock replacement	2,579,664	15
Broilers and other meat-type chickens	908,965	28

Appendix G Colorado Agriculture Overview (USDA, 2015)

2014 STATE AGRICULTURE OVERVIEW

Colorado

† Survey Data from Quick Stats as of: Nov/09/2015

Farms Operations †

Farm Operations - Area Operated, Measured in Acres / Operation	909
Farm Operations - Number of Operations	35,000
Farm Operations - Acres Operated	31,800,000

Livestock Inventory †

Cattle, Cows, Beef - Inventory (First of Jan. 2015)	745,000
Cattle, Cows, Milk - Inventory (First of Jan. 2015)	145,000
Cattle, Incl Calves - Inventory (First of Jan. 2015)	2,600,000
Cattle, On Feed - Inventory (First of Jan. 2015)	930,000
Goats, Meat & Other - Inventory (First of Jan. 2015)	25,000
Goats, Milk - Inventory (First of Jan. 2015)	10,000
Sheep, Incl Lambs - Inventory (First of Jan. 2015)	420,000
Hogs - Inventory (First of Dec. 2014)	700,000

Milk Production †

Milk - Production, Measured in Lb / Head	24,951
Milk - Production, Measured in $	862,320,000
Milk - Production, Measured in Lb	3,593,000,000

Figure 48. Colorado Agriculture Overview (USDA, 2015).

Table 25. Colorado 2012 Ranked Items Within the US Census State Profile (USDA, 2015).

Item	Quantity	U.S. Rank
TOP CROP ITEMS (acres)		
Wheat for grain, all	2,181,967	8
Winter wheat for grain	2,167,930	5
Forage-land used for all hay and haylage, grass silage, and greenchop	1,296,617	18
Corn for grain	1,011,151	15
Corn for silage	157,285	15
TOP LIVESTOCK INVENTORY ITEMS (number)		
Layers	4,195,691	23
Cattle and calves	2,630,082	11
Pullets for laying flock replacement	881,505	26
Hogs and pigs	727,301	16
Sheep and lambs	401,376	3

Appendix H Kansas Agriculture Overview (USDA, 2015)

2014 **STATE AGRICULTURE OVERVIEW**

Kansas

† *Survey Data from Quick Stats as of: Nov/09/2015*

Farms Operations †

Farm Operations - Area Operated, Measured in Acres / Operation	754
Farm Operations - Number of Operations	61,000
Farm Operations - Acres Operated	46,000,000

Livestock Inventory †

Cattle, Cows, Beef - Inventory (First of Jan. 2015)	1,477,000
Cattle, Cows, Milk - Inventory (First of Jan. 2015)	143,000
Cattle, Incl Calves - Inventory (First of Jan. 2015)	6,000,000
Cattle, On Feed - Inventory (First of Jan. 2015)	2,180,000
Goats, Meat & Other - Inventory (First of Jan. 2015)	40,000
Goats, Milk - Inventory (First of Jan. 2015)	4,200
Sheep, Incl Lambs - Inventory (First of Jan. 2015)	66,000
Hogs - Inventory (First of Dec. 2014)	1,840,000

Milk Production †

Milk - Production, Measured in Lb / Head	22,064
Milk - Production, Measured in $	746,640,000
Milk - Production, Measured in Lb	3,111,000,000

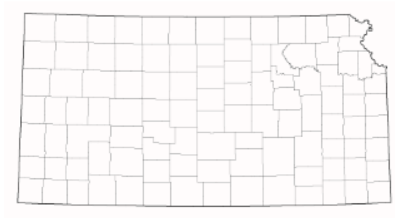


Figure 49. Kansas Agriculture Overview (USDA, 2015).

Table 26. Kansas 2012 Ranked Items Within the US Census State Profile (USDA, 2015).

Item	Quantity	U.S. Rank
TOP CROP ITEMS (acres)		
Wheat for grain, all	9,009,535	1
Winter wheat for grain	9,009,535	1
Corn for grain	3,948,462	7
Soybeans for beans	3,802,588	10
Forage-land used for all hay and haylage, grass silage, and greenchop	2,468,996	6
TOP LIVESTOCK INVENTORY ITEMS (number)		
Cattle and calves	5,922,187	3
Hogs and pigs	1,886,197	10
Layers	(D)	35
Pullets for laying flock replacement	(D)	36
Pheasants	246,132	4

Appendix I Oklahoma Agriculture Overview (USDA, 2015)

2014 STATE AGRICULTURE OVERVIEW

Oklahoma

† Survey Data from Quick Stats as of: Nov/09/2015

Farms Operations [†]

Farm Operations - Area Operated, Measured in Acres / Operation	431
Farm Operations - Number of Operations	79,600
Farm Operations - Acres Operated	34,300,000

Livestock Inventory [†]

Cattle, Cows, Beef - Inventory (First of Jan. 2015)	1,900,000
Cattle, Cows, Milk - Inventory (First of Jan. 2015)	40,000
Cattle, Incl Calves - Inventory (First of Jan. 2015)	4,600,000
Cattle, On Feed - Inventory (First of Jan. 2015)	265,000
Goats, Meat & Other - Inventory (First of Jan. 2015)	95,000
Goats, Milk - Inventory (First of Jan. 2015)	6,900
Sheep, Incl Lambs - Inventory (First of Jan. 2015)	53,000
Hogs - Inventory (First of Dec. 2014)	2,120,000
Chickens, Broilers - Production, Measured in Head	205,300,000

Milk Production [†]

Milk - Production, Measured in Lb / Head	17,425
Milk - Production, Measured in $	180,523,000
Milk - Production, Measured in Lb	697,000,000

Figure 50. Oklahoma Agriculture Overview (USDA, 2015).

(

Table 27. Oklahoma 2012 Ranked Items Within the US Census State Profile (USDA, 2015).

Item	Quantity	U.S. Rank
TOP CROP ITEMS (acres)		
Wheat for grain, all	4,291,939	4
Winter wheat for grain	4,291,939	2
Forage-land used for all hay and haylage, grass silage, and greenchop	2,705,150	3
Corn for grain	294,133	27
Soybeans for beans	259,921	25
TOP LIVESTOCK INVENTORY ITEMS (number)		
Broilers and other meat-type chickens	38,429,952	13
Cattle and calves	4,245,970	5
Layers	3,121,799	26
Hogs and pigs	2,304,740	8
Pullets for laying flock replacement	1,540,444	20

Appendix J New Mexico Agriculture Overview (USDA, 2015)

2014 STATE AGRICULTURE OVERVIEW

New Mexico

† Survey Data from Quick Stats as of: Nov/09/2015

Farms Operations †

Farm Operations - Area Operated, Measured in Acres / Operation	1,749
Farm Operations - Number of Operations	24,700
Farm Operations - Acres Operated	43,200,000

Livestock Inventory †

Cattle, Cows, Beef - Inventory (First of Jan. 2015)	407,000
Cattle, Cows, Milk - Inventory (First of Jan. 2015)	323,000
Cattle, Incl Calves - Inventory (First of Jan. 2015)	1,340,000
Goats, Angora - Inventory (First of Jan. 2015)	11,000
Goats, Meat & Other - Inventory (First of Jan. 2015)	(NA)
Goats, Milk - Inventory (First of Jan. 2015)	(NA)
Sheep, Incl Lambs - Inventory (First of Jan. 2015)	90,000
Hogs - Inventory (First of Dec. 2014)	1,300

Milk Production †

Milk - Production, Measured in Lb / Head	25,093
Milk - Production, Measured in $	1,807,415,000
Milk - Production, Measured in Lb	8,105,000,000

Figure 51. New Mexico Agriculture Overview (USDA, 2015).

Table 28. New Mexico 2012 Ranked Items Within the US Census State Profile (USDA, 2015).

Item	Quantity	U.S. Rank
TOP CROP ITEMS (acres)		
Forage-land used for all hay and haylage, grass silage, and greenchop	343,032	37
Wheat for grain, all	87,504	35
Winter wheat for grain	86,434	33
Corn for silage	81,866	22
Pecans, all	41,331	4
TOP LIVESTOCK INVENTORY ITEMS (number)		
Cattle and calves	1,354,240	22
Sheep and lambs	89,745	17
Layers	66,653	47
Horses and ponies	50,723	36
Goats, all	30,981	26

Appendix K Texas Agriculture Overview (USDA, 2015)

2014 STATE AGRICULTURE OVERVIEW

Texas

† Survey Data from Quick Stats as of: Nov/09/2015

Farms Operations †

Farm Operations - Area Operated, Measured in Acres / Operation	530
Farm Operations - Number of Operations	245,500
Farm Operations - Acres Operated	130,000,000

Livestock Inventory †

Cattle, Cows, Beef - Inventory (First of Jan. 2015)	4,180,000
Cattle, Cows, Milk - Inventory (First of Jan. 2015)	470,000
Cattle, Incl Calves - Inventory (First of Jan. 2015)	11,800,000
Cattle, On Feed - Inventory (First of Jan. 2015)	2,510,000
Goats, Angora - Inventory (First of Jan. 2015)	85,000
Goats, Meat & Other - Inventory (First of Jan. 2015)	820,000
Goats, Milk - Inventory (First of Jan. 2015)	23,000
Sheep, Incl Lambs - Inventory (First of Jan. 2015)	720,000
Hogs - Inventory (First of Dec. 2014)	810,000
Chickens, Broilers - Production, Measured in Head	591,800,000

Milk Production †

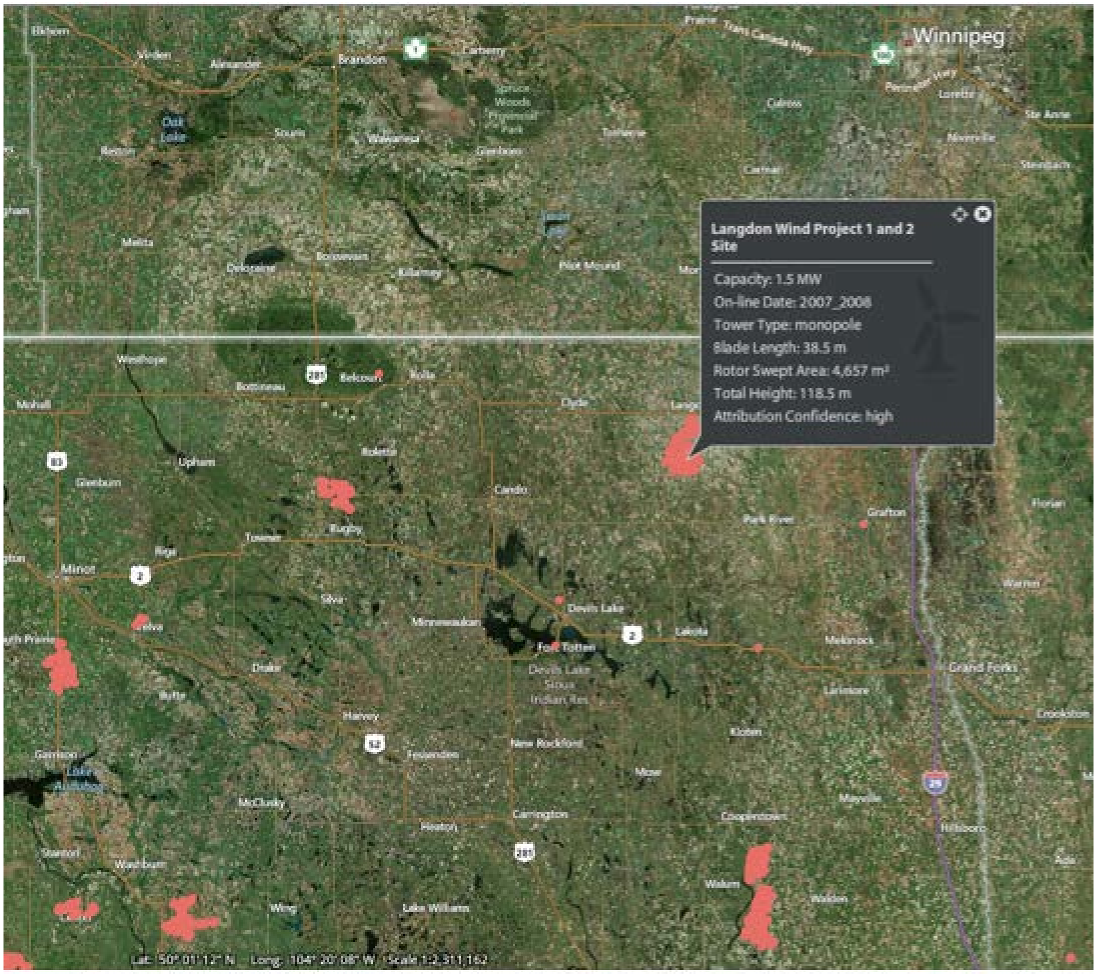
Milk - Production, Measured in Lb / Head	22,268
Milk - Production, Measured in $	2,536,260,000
Milk - Production, Measured in Lb	10,310,000,000

Figure 52. Texas Agriculture Overview (USDA, 2015).

Table 29. Texas 2012 Ranked Items Within the US Census State Profile (USDA, 2015).

Item	Quantity	U.S. Rank
TOP CROP ITEMS (acres)		
Forage-land used for all hay and haylage, grass silage, and greenchop	5,069,579	1
Cotton, all	3,844,464	1
Upland cotton	3,835,216	1
Wheat for grain, all	2,993,969	5
Winter wheat for grain	2,989,113	3
TOP LIVESTOCK INVENTORY ITEMS (number)		
Broilers and other meat-type chickens	107,351,698	6
Layers	20,902,244	5
Cattle and calves	11,159,747	1
Pullets for laying flock replacement	6,244,474	7
Turkeys	1,747,526	17

Appendix L Langdon Wind Farm



Reference: http://eerscmap.usgs.gov/windfarm/

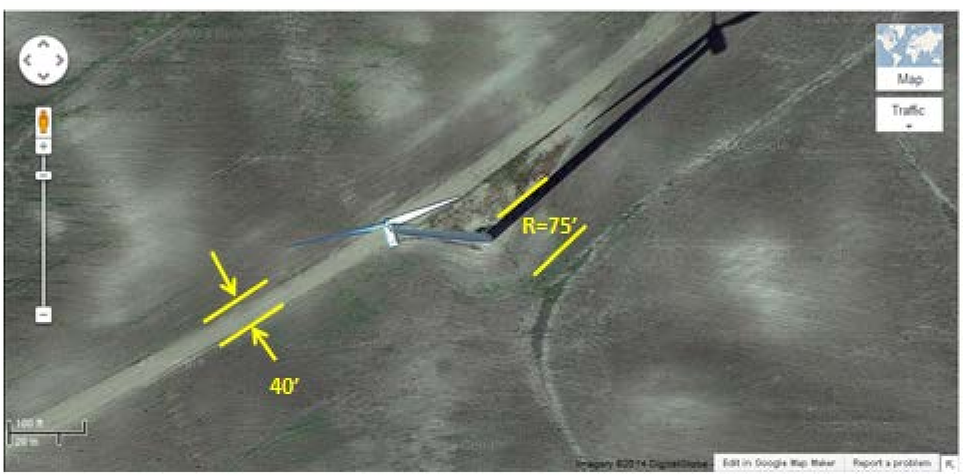
Figure 53. Langdon Wind Farm Overview.

Langdon Wind Farm, North Dakota Overview

Reference: http://eerscmap.usgs.gov/windfarm/

Figure 54. Langdon Wind Farm with defined measurement areas.

Langdon Wind Farm, North Dakota Overview



Access Roads are approximately 40 feet wide including right-of-way.
Wind Turbine foundations are ~150 feet in diameter = 17,671 ft^2 = 0.41 acre.
133 Wind Turbines * 0.41 acres each = **54.53 acres for all foundations.**

Figure 55. Langdon Wind Farm Access Roads

Langdon Wind Farm, North Dakota Area 1

Area 1 (9 Turbines) Access Roads = (5700 + 5600) * 40 = 452,000 ft^2 = 10.38 acres.

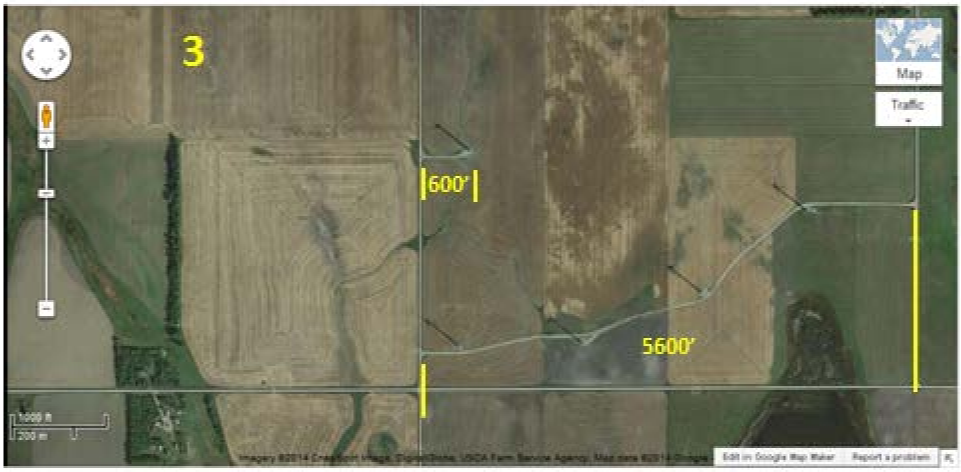
Figure 56. Langdon Wind Farm Area 1.

Langdon Wind Farm, North Dakota Area 2

Area 2 (7 Turbines) Access Roads = (7900 + 700) * 40 = 344,000 ft^2 = 7.90 acres.

Figure 57. Langdon Wind Farm Area 2.

Landgon Wind Farm, North Dakota Area 3



Area 3 (5 Turbines) Access Roads = (600 + 5600) * 40 = 248,000 ft^2 = 5.69 acres.

Figure 58. Langdon Wind Farm Area 3.

Langdon Wind Farm, North Dakota Area 4

Area 4 (6 Turbines) Access Roads = (4100 + 2400) * 40 = 260,000 ft^2 = 5.97 acres.

Figure 59. Langdon Wind Farm Area 4.

Langdon Wind Farm, North Dakota Area 5

Area 5 (6 Turbines) Access Roads = 6100 * 40 = 244,000 ft^2 = 5.60 acres.

Figure 60. Langdon Wind Farm Area 5.

Langdon Wind Farm, North Dakota Area 6

Area 6 (4 Turbines) Access Roads = (4700 + 1000) * 40 = 228,000 ft^2 = 5.23 acres.

Figure 61. Langdon Wind Farm Area 6.

Langdon Wind Farm, North Dakota Area 7

Area 7 (4 Turbines) Access Roads = (3700 + 1700) * 40 = 216,000 ft^2 = 4.96 acres.

Figure 62. Langdon Wind Farm Area 7.

Langdon Wind Farm, North Dakota Area 8

Area 8 (6 Turbines) Access Roads = 9100 * 40 = 364,000 ft^2 = 8.36 acres.

Figure 63. Langdon Wind Farm Area 8.

Langdon Wind Farm, North Dakota Area 9

Area 9 (3 Turbines) AccessRoads = 4000 * 40 = 160,000 ft^2 = 3.67 acres.

Figure 64. Langdon Wind Farm Area 9.

Langdon Wind Farm, North Dakota Area 10

Area 10 (21 Turbines) AccessRoads = (6900 + 9400 + 4300 + 4000) * 40 = 984,000 ft^2 = 22.59acres.

Figure 65. Langdon Wind Farm Area 10.

Langdon Wind Farm, North Dakota Area 11

Area 11 (5 Turbines) Access Roads = 6100 * 40 = 244,000 ft^2 = 5.60 acres.

Figure 66. Langdon Wind Farm Area 11.

Langdon Wind Farm, North Dakota Area 12

Area 12 (10 Turbines) Access Roads = (600 + 6000 + 5400) * 40 = 480,000 ft^2 = 11.02 acres.

Figure 67. Langdon Wind Farm Area 12.

Langdon Wind Farm, North Dakota Area 13

Area 13 (3 Turbines) Access Roads = 5000 * 40 = 200,000 ft^2 = 4.59 acres.

Figure 68. Langdon Wind Farm Area 13.

Langdon Wind Farm, North Dakota Area 14

Area 14 (9 Turbines) Access Roads = 10,300 * 40 = 200,000 ft^2 = 9.46 acres.

Figure 69. Langdon Wind Farm Area 14.

Langdon Wind Farm, North Dakota Area 15

Area 15 (15 Turbines) Access Roads = (3700 + 10000+ 4600 +900 + 4600) * 40 = 952,000 ft^2 = 21.85 acres.

Figure 70. Langdon Wind Farm Area 15.

Langdon Wind Farm, North Dakota Area 16

Area 16 (7 Turbines) Access Roads = (5700 + 3400) * 40 = 364,000 ft^2 = 8.36 acres.

Figure 71. Langdon Wind Farm Area 16.

Langdon Wind Farm, North Dakota Area 17

Area 17 (7 Turbines) Access Roads = 11,400 * 40 = 456,000 ft^2 = 10.47 acres.

Figure 72. Langdon Wind Farm Area 17.

Langdon Wind Farm, North Dakota Area 18

Area 18 (1 Turbine) Access Road = 600 * 40 = 24,000 ft^2 = 0.55 acres.

Figure 73. Langdon Wind Farm Area 18.

Langdon Wind Farm, North Dakota Area 19

Area 19 (6 Turbines) AccessRoads = 8100 * 40 = 324,000 ft^2 = 7.44 acres.

Figure 74. Langdon Wind Farm Area 19.

Table 30. Langdon Wind Farm Summary.

Langdon Wind Farm, North Dakota

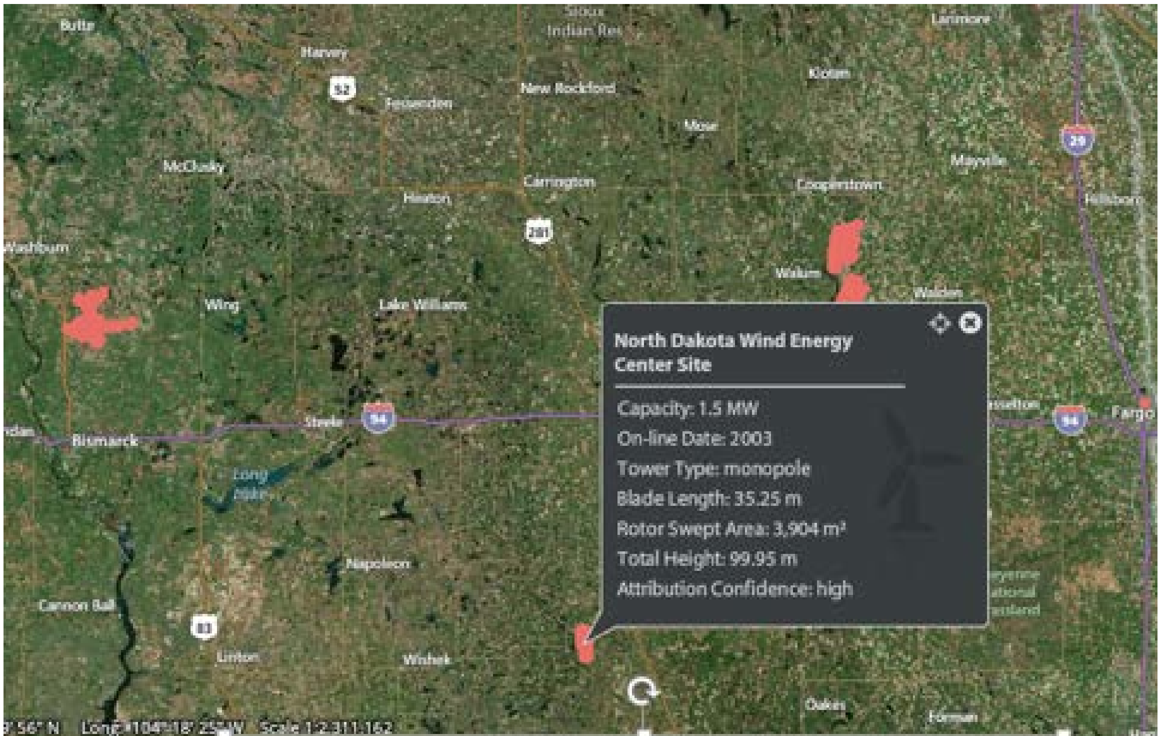
Wind Farm Name	State	No. of Turbines	Capacity MW	Gross Total Area (acres)	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	Hectares per MW	Gross MJ per Hectare	Transmission Voltage	Commissioned	Electricity Purchaser	Owner / Operator
Langdon Wind	ND	133	199.5	30400	12302	62	61.67	58.38	115 kV	2008	Minnkota Power Co.	Otter Tail Power Co.

Information is based on gross area of the Wind Farm measured from Google maps.

Wind Farm Name	State	No. of Turbines	Capacity MW	Actual Total Area (acres)	Permanently Disturbed (hectares)	Total Area Per Unit Capacity Hectares/MW	New MJ per Hectare	Electricity Purchaser	Owner / Operator	Turbine Foundation Area (acre)	Access Roads (acre)	Substation Area (acre)	CO2 Savings metric tonnes/yr	Type of Turbine	Turbine Nameplate (MW)
Langdon Wind	ND	133	199.5	209	85	0.42	8483	Minnkota Power Co.	Otter Tail Power Co.	55	155		Unknown	GE	1.5

Using only the permanently disturbed land for the Wind Farm (access roads, substation, wind turbine foundation and structure, etc.), the MJ per Hectare increases from 58.38 to 8483 MJ per Hectare.

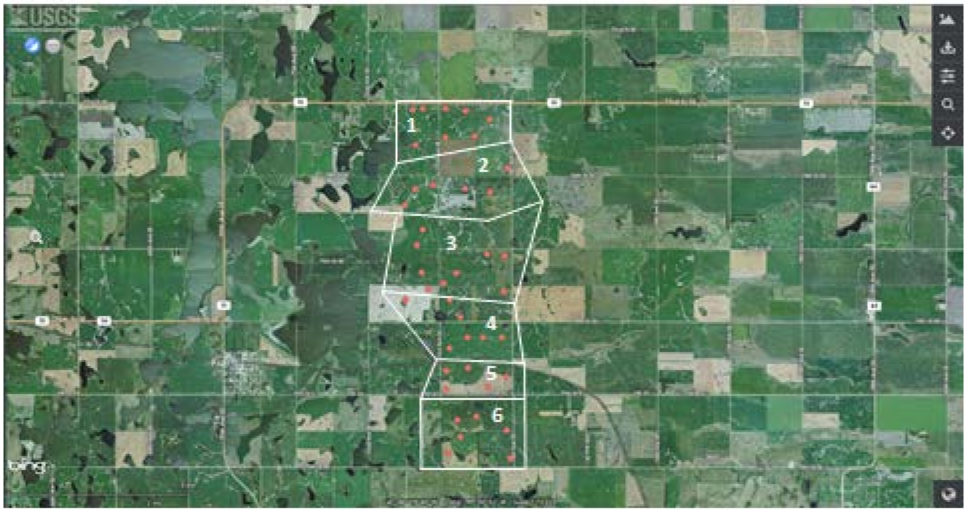
Appendix M North Dakota Wind Energy (North Dakota I and II) Wind Farm



Reference: http://eerscmap.usgs.gov/windfarm/

Figure 75. North Dakota Wind Farm Overview.

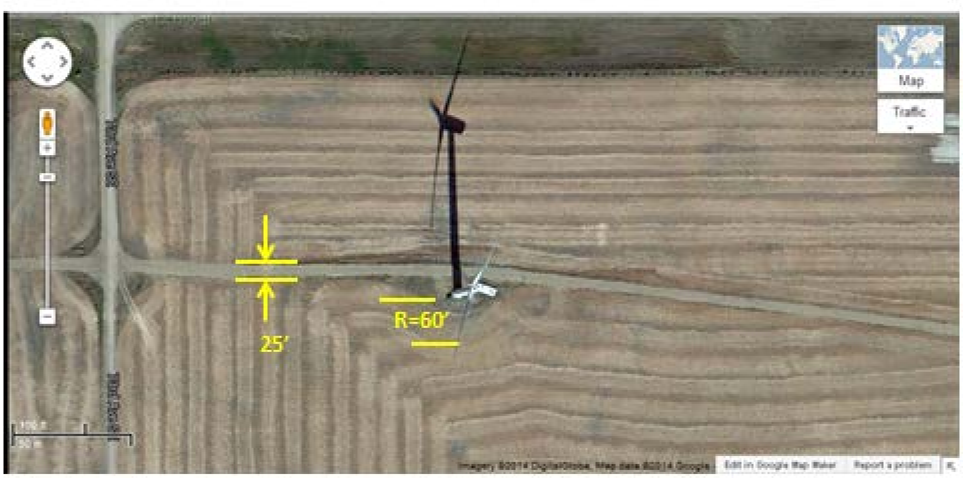
North Dakota Wind Energy, North Dakota Overview



Reference: http://eerscmap.usgs.gov/windfarm/

Figure 76. North Dakota Wind Farm with Defined Measurement Areas.

North Dakota Wind Energy, North Dakota Overview



Access Roads are approximately 25 feet wide including right-of-way.
Wind Turbine foundations are ~120 feet in diameter = 11,310 ft^2 = 0.26 acre.
41 Wind Turbines * 0.26 acres each = **10.66 acres for all foundations.**

Figure 77. North Dakota Wind Farm Access Roads.

North Dakota Wind Energy, North Dakota Area 1

Area 1 (8 Turbines) AccessRoads = (6900 + 3700) * 25 = 265,000 ft^2 = 6.08 acres.

Figure 78. North Dakota Wind Farm Area 1.

North Dakota Wind Energy, Substation

Area 1 Substation = 350 * 360 = 126,000 ft^2 = 2.89 acres.

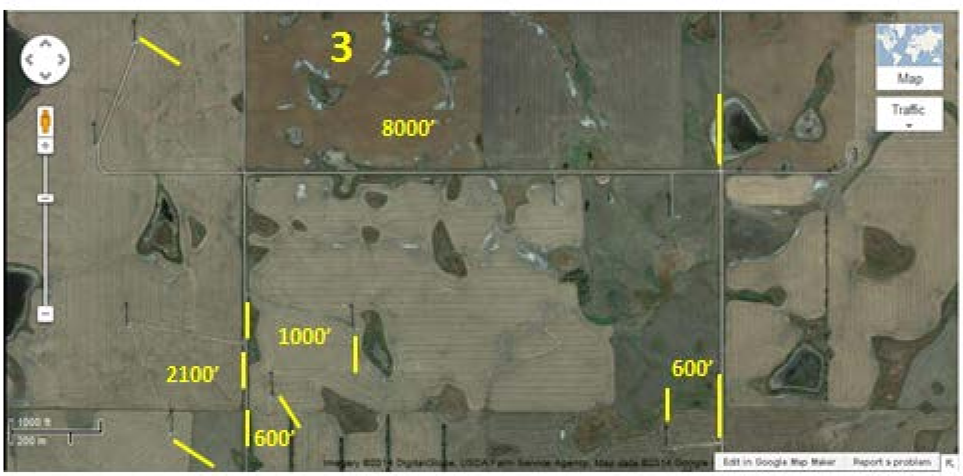
Figure 79. North Dakota Wind Farm Substation.

North Dakota Wind Energy, North Dakota Area 2

Area 2 (6 Turbines) Access Roads = (300 + 7700) * 25 = 200,000 ft^2 = 4.59 acres.

Figure 80. North Dakota Wind Farm Area 2.

North Dakota Wind Energy, North Dakota Area 3



Area 3 (9 Turbines) Access Roads = (2100 + 1000 + 600 + 8000 + 600) * 25 = 307,500 ft^2 = 7.06 acres.

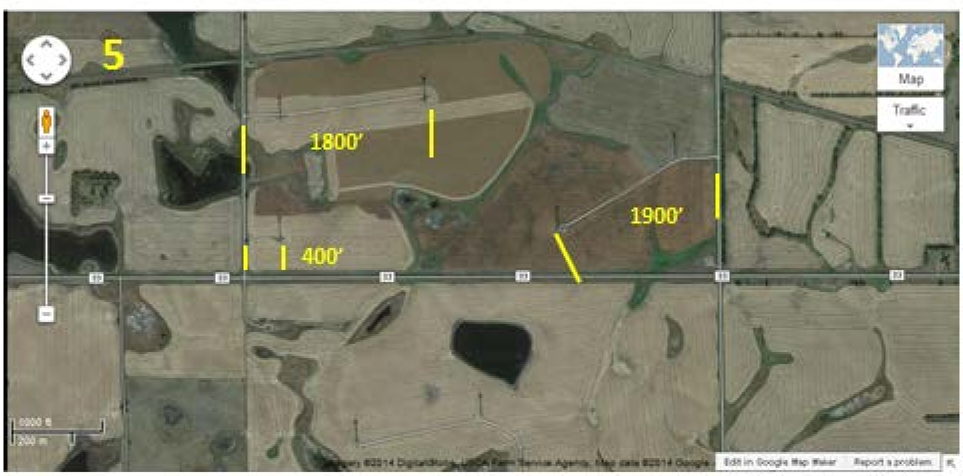
Figure 81. North Dakota Wind Farm Area 3.

North Dakota Wind Energy, North Dakota Area 4

Area 4 (7 Turbines) Access Roads = (1600 + 400 + 5000 + 600) * 25 = 190,000 ft^2 = 4.36 acres.

Figure 82. North Dakota Wind Farm Area 4.

North Dakota Wind Energy, North Dakota Area 5



Area 5 (5 Turbines) Access Roads = (1800 + 400 + 1900) * 25 = 102,500 ft^2 = 2.35 acres.

Figure 83. North Dakota Wind Farm Area 5.

North Dakota Wind Energy, North Dakota Area 6

Area 6 (6 Turbines) Access Roads = (2400 + 5700 + 300) * 25 = 210,000 ft^2 = 4.82 acres.

Figure 84. North Dakota Wind Farm Area 6.

Table 31. North Dakota Wind Farm Summary.

North Dakota Wind Energy, North Dakota

Wind Farm Name	State	No. of Turbines	Capacity MW	Gross Total Area (acres)	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	Hectares per MW	Gross MJ per Hectare	Transmission Voltage	Commissioned	Electricity Purchaser	Owner / Operator
North Dakota I & II	ND	41	61.5	3500	1416	23	23.03	156.31	41.6 kV	2003	NextEra Energy	FPL Energy

Information is based on gross area of the Wind Farm measured from Google maps.

Wind Farm Name	State	No. of Turbines	Capacity MW	Actual Total Area (acres)	Permanently Disturbed (hectares)	Total Area Per Unit Capacity Hectares/MW	New MJ per Hectare	Electricity Purchaser	Owner / Operator	Turbine Foundation Area (acre)	Access Roads (acre)	Substation Area (acre)	CO2 Savings metric tonnes/yr	Type of Turbine	Turbine Nameplate (MW)
North Dakota I & II	ND	41	61.5	43	17	0.28	12780	NextEra Energy	FPL Energy	11	29	3	Unknown	GE	1.5

Using only the permanently disturbed land for the Wind Farm (access roads, substation, wind turbine foundation and structure, etc.), the MJ per Hectare increases from 156.31 to 12780 MJ per Hectare.

Appendix N Tatanka Wind Farm

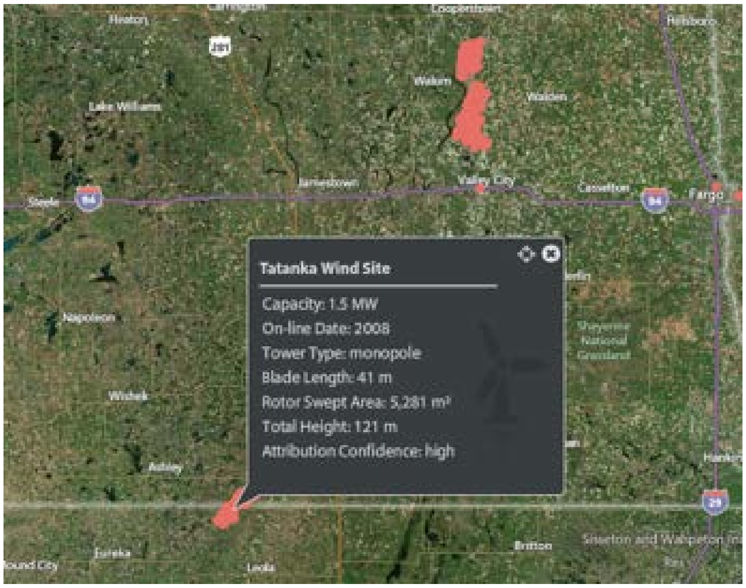
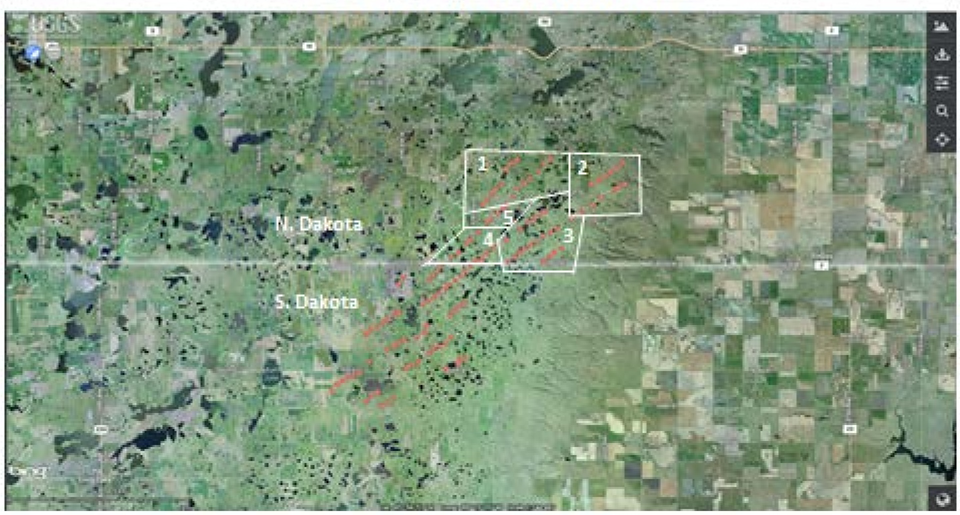


Figure 85. Tatanka Wind Farm Overview.

Tatanka Wind, North Dakota Overview



Reference: http://eerscmap.usgs.gov/windfarm/

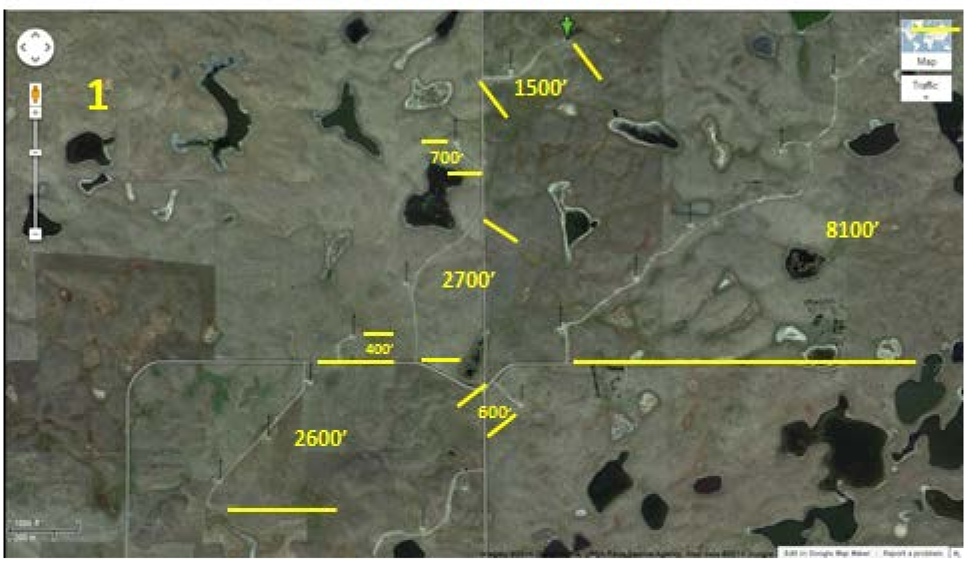
Figure 86. Tatanka Wind Fam with Defined Measurement Areas.

Tatanka Wind Farm, North Dakota Overview

Access Roads are approximately 40 feet wide including right-of-way.
Wind Turbine foundations are ~100 feet in diameter = 7,854 ft^2 = 0.18 acre.
61 Wind Turbines * 0.18 acres each = **11.00 acres for all foundations.**

Figure 87. Tatanka Wind Farm Access Roads.

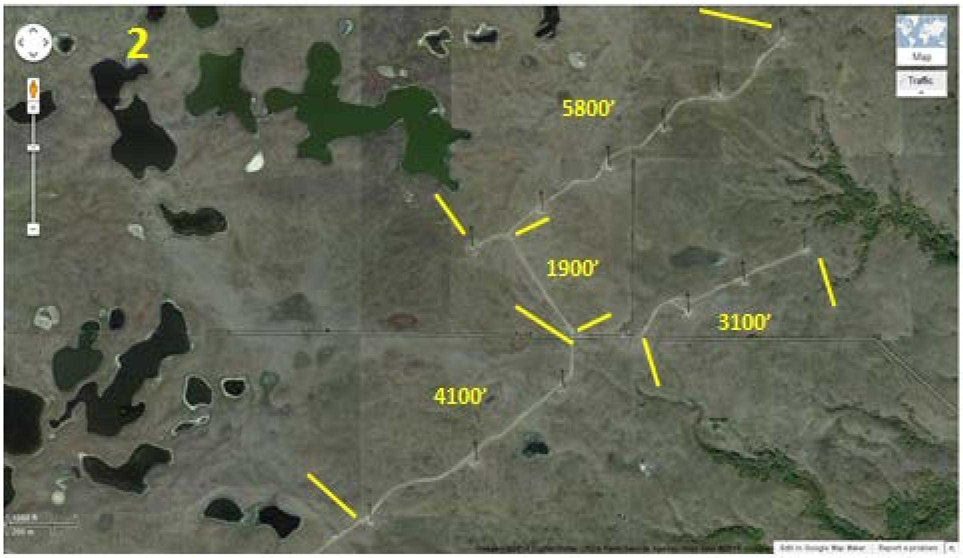
Tatanka Wind Farm, North Dakota Area 1



Area 1 (15 Turbines) Access Roads = (2600 + 400 + 600 + 2700 + 700 + 1500 + 8100) * 40 = 664,000 ft^2 = 15.24 acres.

Figure 88. Tatanka Wind Farm Area 1.

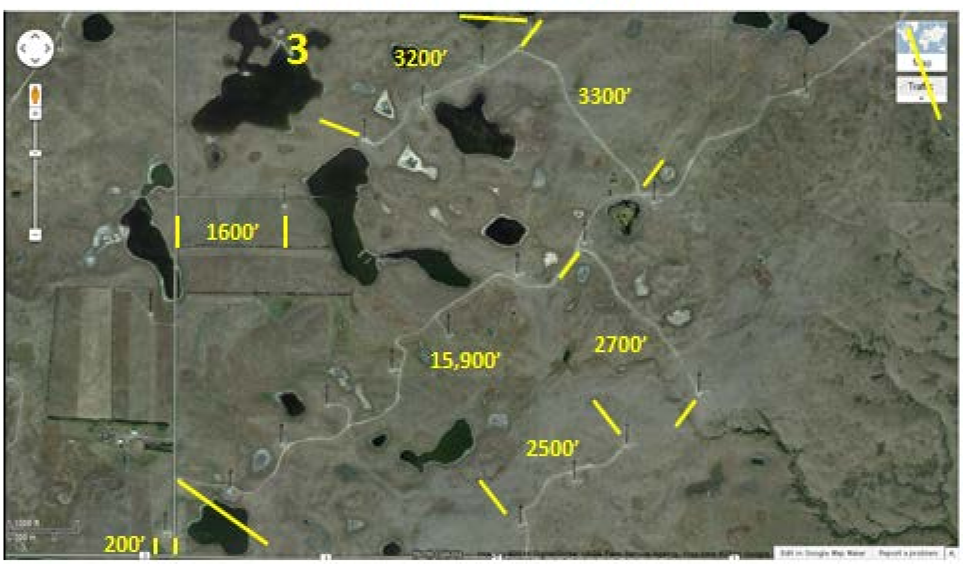
Tatanka Wind Farm, North Dakota Area 2



Area 2 (12 Turbines) Access Roads = (4100 + 1900 + 5800 + 3100) * 40 = 596,000 ft² = 13.68 acres.

Figure 89. Tatanka Wind Farm Area 2.

Tatanka Wind Farm, North Dakota Area 3



Area 3 (20 Turbines) Access Roads = (200 + 1600 + 3200 + 3300 + 15,900 + 2700 + 2500) * 40 = 1,176,000 ft² = 27.00 acres.

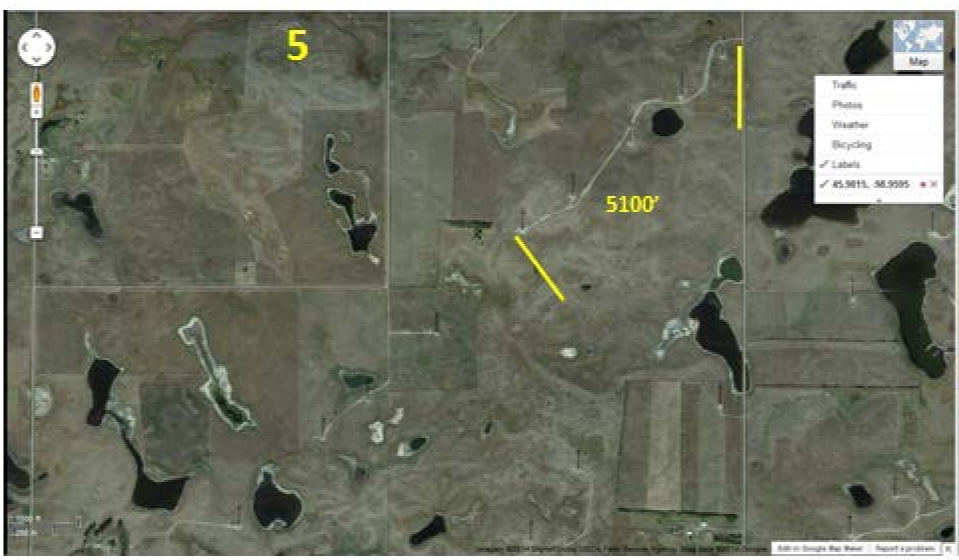
Figure 90. Tatanka Wind Farm Area 3.

Tatkanka Wind Farm, North Dakota Area 4

Area 4 (9 Turbines) Access Roads = (2800 + 2800 + 800 + 4000) * 40 = 416,000 ft^2 = 9.55 acres.

Figure 91. Tatanka Wind Farm Area 4.

Tatanka Wind Farm, North Dakota Area 5



Area 5 (5 Turbines) Access Roads = 5100 * 40 = 204,000 ft^2 = 4.68 acres.

Figure 92. Tatanka Wind Farm Area 5.

Table 32. Tatanka Wind Farm Summary.

Tatanka Wind Farm, North Dakota

Wind Farm Name	State	No. of Turbines	Capacity MW	Gross Total Area (acres)	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	Hectares per MW	Gross MJ per Hectare	Transmission Voltage	Commissioned	Electricity Purchaser	Owner / Operator
Tatanka Wind Farm	ND	61	92	7040	2849	31	31.14	115.62	230 kV	2008	Midwest Independent Transmission System Operator	Acciona Energy

Information is based on gross area of the Wind Farm measured from Google maps.

Wind Farm Name	State	No. of Turbines	Capacity MW	Actual Total Area (acres)	Permanently Disturbed (hectares)	Total Area Per Unit Capacity Hectares/MW	New MJ per Hectare	Turbine Foundation Area (acre)	Access Roads (acre)	Substation Area (acre)	CO2 Savings metric tonnes/yr	Type of Turbine	Turbine Namplate (MW)
Tatanka Wind Farm	ND	61	92	81	33	0.36	10030	11	70.15		275,000	Acciona	1.5

Using only the permanently disturbed land for the Wind Farm (access roads, substation, wind turbine foundation and structure, etc.), the MJ per Hectare increases from 115.62 to 10,030 MJ per Hectare.

Appendix O Ashtabula I Wind Farm

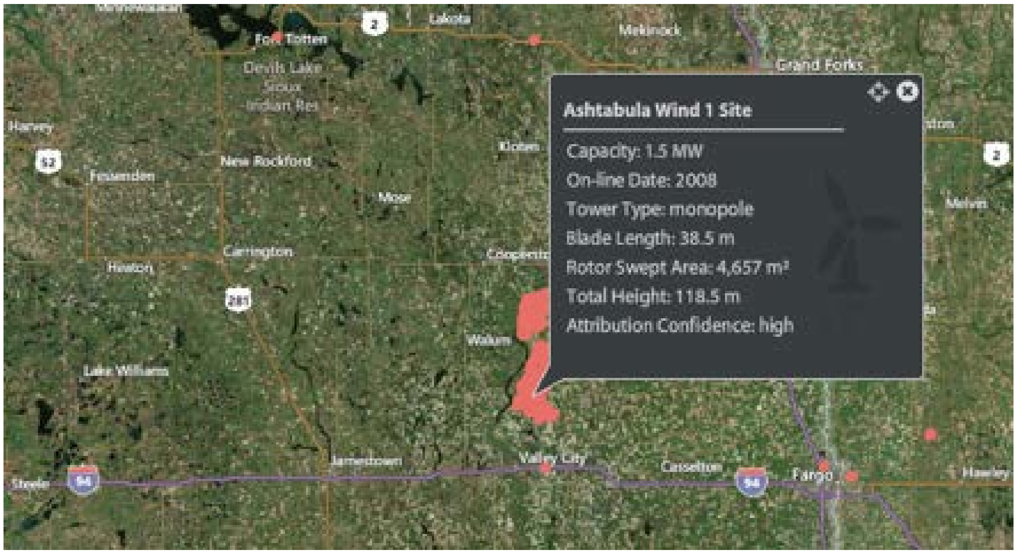
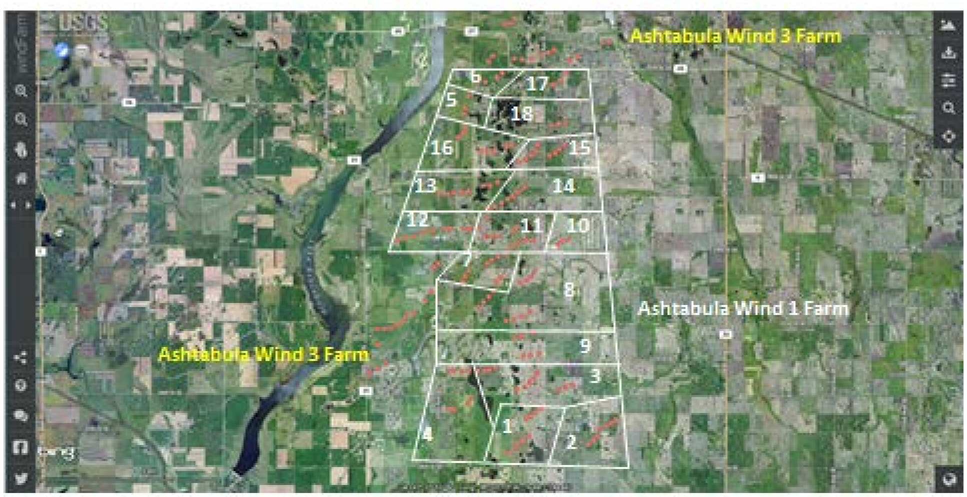


Figure 93. Ashtabula I Wind Farm Overview.

Ashtabula Wind I Farm, North Dakota Overview



Reference: http://eerscmap.usgs.gov/windfarm/

Figure 94. Ashtabula I Wind Farm with Defined Measurement Areas.

Ashtabula I Wind Farm, North Dakota Overview

Access Roads are approximately 50 feet wide.
Wind Turbine foundations are ~120 feet in diameter = 11310 ft^2 = 0.26 acre.
131 Wind Turbines * 0.26 acres each = **34.06 acres for all foundations.**

Figure 95. Ashtabula I Wind Farm Access Roads.

Ashtabula I Wind Farm, North Dakota Area 1

Area 1 (8 Turbines) Access Roads = (4900 + 5500) * 50 = 520,000 ft^2 = 11.94 acres.

Figure 96. Ashtabula I Wind Farm Area 1.

Ashtabula I Wind Farm, North Dakota Area 2

Area 2 (7 Turbines) Access Roads = 6700 * 50 = 335,000 ft^2 = 7.69 acres.

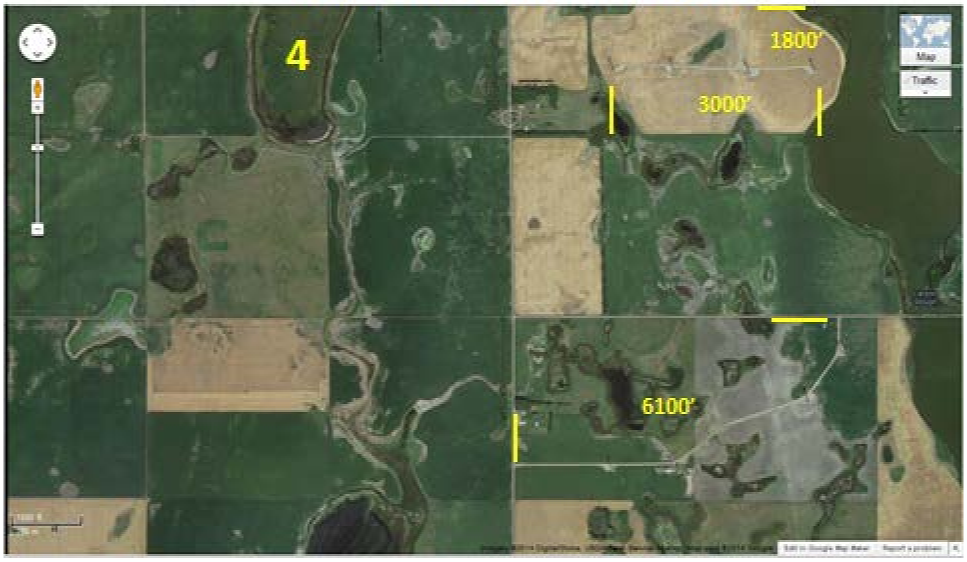
Figure 97. Ashtabula Wind Farm Area 2.

Ashtabula I Wind Farm, North Dakota Area 3

Area 3 (12 Turbines) Access Roads = (3300 + 1000 + 5200 + 1600) * 50 = 550,000 ft^2 = 12.74 acres.

Figure 98. Ashtabula I Wind Farm Area 3.

Ashtabula I Wind Farm, North Dakota Area 4



Area 4 (8 Turbines) Access Roads = (3000 + 1800 + 6100) * 50 = 545,000 ft^2 = 12.51 acres.

Figure 99. Ashtabula I Wind Farm Area 4.

Ashtabula I Wind Farm, North Dakota Area 5

Area 5 (3 Turbines) Access Roads = (1700 + 700) * 50 = 120,000 ft^2 = 2.75 acres.

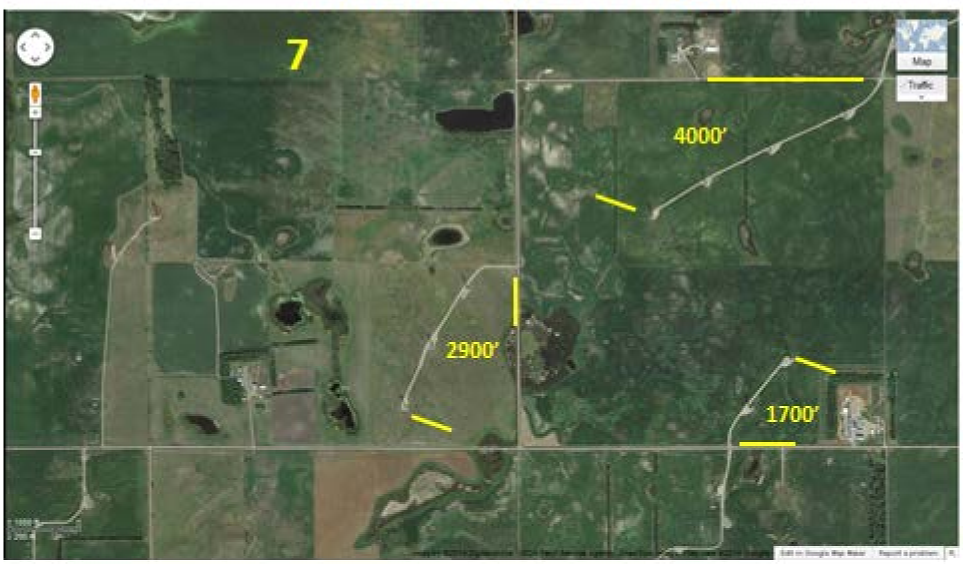
Figure 100. Ashtabula I Wind Farm Area 5.

Ashtabula I Wind Farm, North Dakota Area 6

Area 6 (4 Turbines) Access Roads = 5400 * 50 = 270,000 ft^2 = 6.20 acres.

Figure 101. Ashtabula I Wind Farm Area 6.

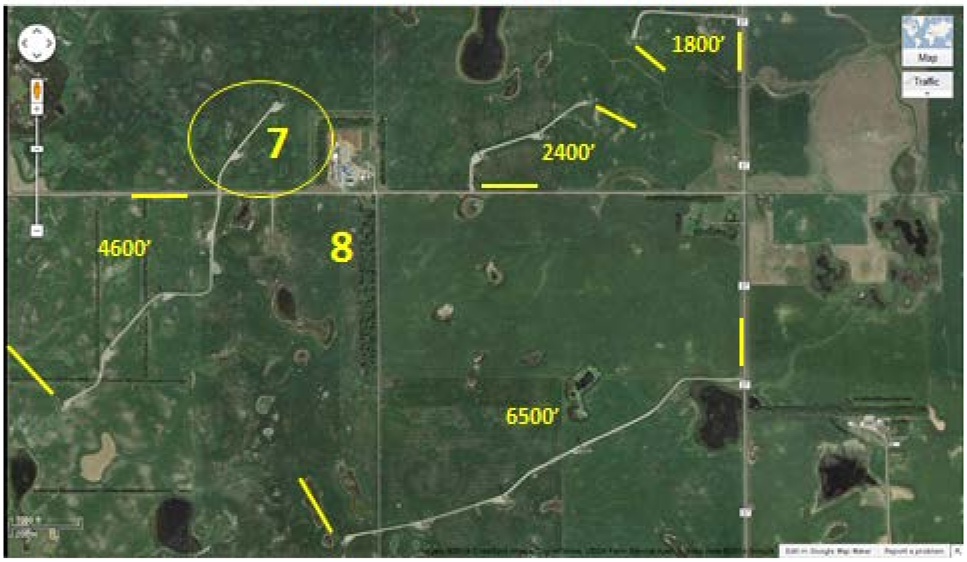
Ashtabula I Wind Farm, North Dakota Area 7



Area 7 (11 Turbines) Access Roads = (2900 + 4000 + 1700) * 50 = 430,000 ft^2 = 9.87 acres.

Figure 102. Ashtabula I Wind Farm Area 7.

Ashtabula I Wind Farm, North Dakota Area 8



Area 8 (12 Turbines) Access Roads = (4600 + 6500 + 2400 + 1800) * 50 = 765,000 ft^2 = 17.56 acres.

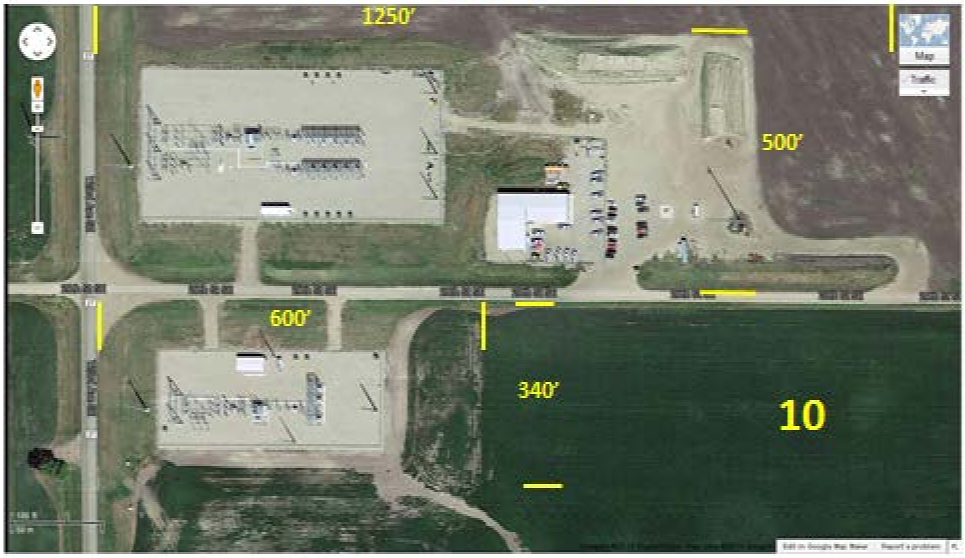
Figure 103. Ashtabula I Wind Farm Area 8.

Ashtabula I Wind Farm, North Dakota Area 9

Area 9 (6 Turbines) Access Roads = (4700 + 3900) * 50 = 430,000 ft^2 = 9.87 acres.

Figure 104. Ashtabula I Wind Farm Area 9.

Ashtabula I Wind Farm, North Dakota Substation



Area 10 Substation = (1250 * 500) + (600 * 340) = 625,000 ft^2 + 204,000 ft^2 = 19.03 acres.

Figure 105. Ashtabula I Wind Farm Substation.

Ashtabula I Wind Farm, North Dakota Area 10

Area 10 (3 Turbines) Access Roads = 2800 * 50 = 140,000 ft^2 = 3.21 acres.

Figure 106. Ashtabula I Wind Farm Area 10.

Ashtabula I Wind Farm, North Dakota Area 11

Area 11 (11 Turbines) Access Roads = (3700 + 7400 + 4300) * 50 = 770,000 ft^2 = 17.68 acres.

Figure 107. Ashtabula I Wind Farm Area 11.

Ashtabula I Wind Farm, North Dakota Area 12

Area 12 (10 Turbines) Access Roads = 12300 * 50 = 615,000 ft^2 = 14.12 acres.

Figure 108. Ashtabula I Wind Farm Area 12.

Ashtabula I Wind Farm, North Dakota Area 13

Area 13 (8 Turbines) Access Roads = (5100 + 3500) * 50 = 430,000 ft² = 9.87 acres.

Figure 109. Ashtabula I Wind Farm Area 13.

Ashtabula I Wind Farm, North Dakota Area 14

Area 14 (7 Turbines) Access Roads = 9500 * 50 = 477,500 ft² = 10.96 acres.

Figure 110. Ashtabula Wind Farm Area 14.

Ashtabula I Wind Farm, North Dakota Area 15

Area 15 (9 Turbines) Access Roads = (5700 + 3500) * 50 = 460,000 ft^2 = 10.56 acres.

Figure 111. Ashtabula I Wind Farm Area 15.

Ashtabula I Wind Farm, North Dakota Area 16

Area 16 (9 Turbines) Access Roads = (3900 + 6800) * 50 = 535,000 ft^2 = 12.28 acres.

Figure 112. Ashtabula I Wind Farm Area 16.

Ashtabula I Wind Farm, North Dakota Area 17

Area 17 (3 Turbines) Access Roads = 4600 * 50 = 230,000 ft^2 = 5.28 acres.

Figure 113. Ashtabula I Wind Farm Area 17.

Ashtabula I Wind Farm, North Dakota Area 18

Area 18 (3 Turbines) Access Roads = 3100 * 50 = 157,500 ft^2 = 3.62 acres.

Figure 114. Ashtabula I Wind Farm Area 18.

Table 33. Ashtabula I Wind Farm Summary

Ashtabula I Field Wind Farm, North Dakota

Wind Farm Name	State	No. of Turbines	Capacity MW	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	Hectares per MW	Gross MJ per Hectare	Transmission Voltage	Commissioned	Electricity Purchaser	Owner / Operator
Ashtabula Wind Center I	ND	131	196.5	19943	101	101.49	35.47	230 kV	2008	Minkota Power Co.	NextEra Energy

Information is based on gross area of the Wind Farm measured from Google maps.

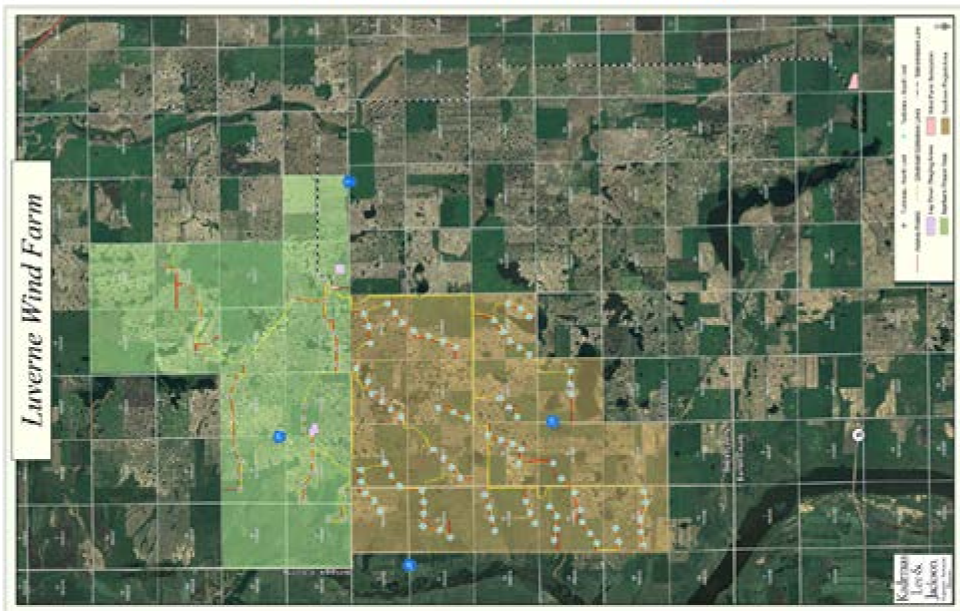
Wind Farm Name	State	No. of Turbines	Capacity MW	Actual Total Area (acres)	Permanently Disturbed (hectares)	Total Area Per Unit Capacity Hectares/MW	New MJ per Hectare	Turbine Foundation Area (acre)	Access Roads (acre)	Substation Area (acre)	CO2 Savings metric tonnes/yr	Type of Turbine	Turbine Nameplate (MW)
Ashtabula Wind Center I	ND	131	196.5	232	94	0.48	7541	34	179	19	Unknown	GE XLE	1.5

Using only the permanently disturbed land for the Wind Farm (access roads, substation, wind turbine foundation and structure, etc.), the MJ per Hectare increases from 35.47 to 7541 MJ per Hectare.

Appendix P Ashtabula II Wind Farm

Ashtabula II (Also Known As Luverne South Field) Wind Farm

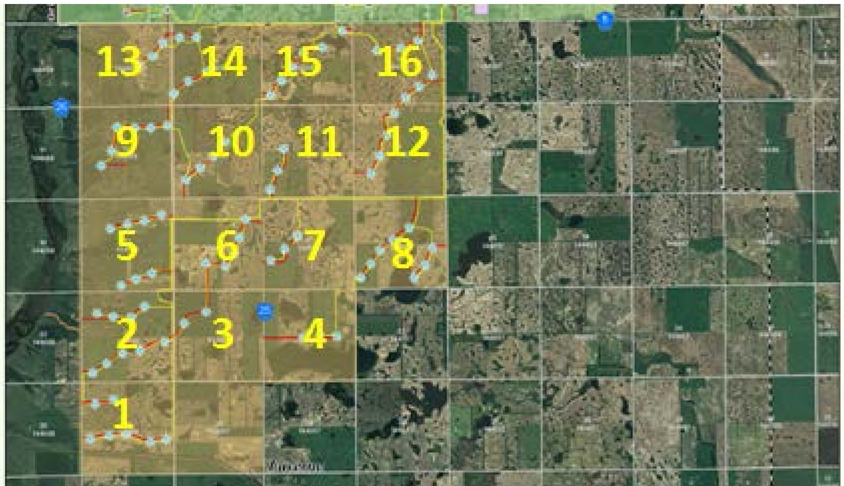
Luverne Wind Farm, North Dakota Overview



Reference: http://mpowernd.com/?page=Projects

Figure 115. Ashtabula II Wind Farm Defined Measurement Areas

Ashtabula II Wind Farm, North Dakota Overview



Turbines - North Unit
Turbines - South Unit
Access Roads
Electrical Collection Lines
Transmission Line
Lay Down Staging Areas
Wind Farm Substation
Northern Project Area
Southern Project Area

Each project area = 1 sq. mile = 640 acres.
South Field = 17 square miles =
10880 acres.

Reference: http://mpowernd.com/?page=Projects

Figure 116. Ashtabula II Wind Farm Defined Measurement Areas.

Ashtabula II Wind Farm, North Dakota Overview

Access Roads are approximately 40 feet wide.
Wind Turbine foundations are 80 feet in diameter = 5026 ft^2 = 0.12 acre.
80 Wind Turbines * 0.12 acres each = **9.6 acres for all foundations.**

Figure 117. Ashtabula II Wind Farm Access Roads.

Ashtabula II Wind Farm, North Dakota Area 1

Area 1 Access Roads = (1850 + 2500 + 1100 + 900) * 40 = 254,000 ft^2 = 5.83 acres.

Figure 118. Ashtabula II Wind Farm Area 1.

Ashtabula II Wind Farm, North Dakota Area 2

Area 2 Access Roads = (3000 + 850 + 700 + 2250 + 1500 + 2100) * 40 = 416,000 ft^2 = 9.55 acres.

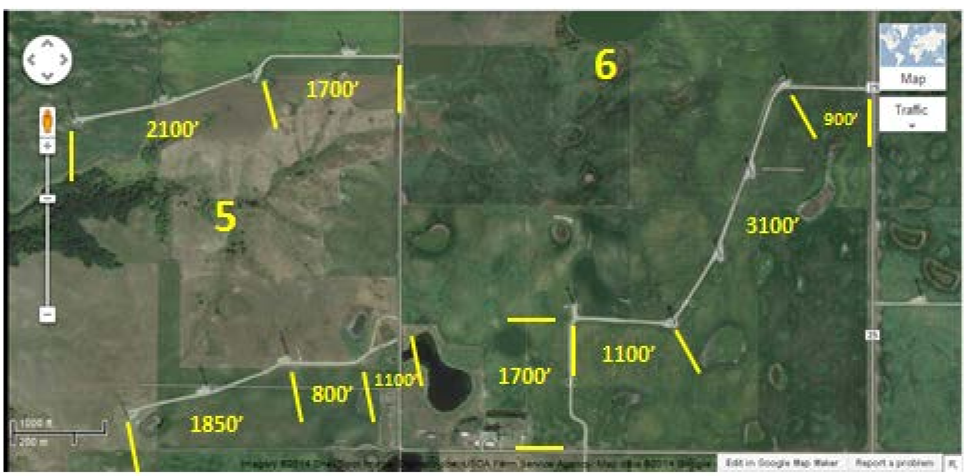
Figure 119. Ashtabula II Wind Farm Area 2.

Ashtabula II Wind Farm, North Dakota Areas 3 & 4

Area 3 Access Roads = (500 + 1300 + 1450 + 1300) * 40 = 182,000 ft^2 = 4.18 acres.
Area 4 Access Roads = 4500 * 40 = 180,000 ft^2 = 4.13 acres.

Figure 120. Ashtabula II Wind Farm Areas 3 and 4

Ashtabula II Wind Farm, North Dakota Areas 5 & 6



Area 5 Access Roads = (1850 + 800 + 1100 + 2100 + 1700) * 40 = 302,000 ft^2 = 6.93 acres.
Area 6 Access Roads = (1700 + 1100 + 3100 + 900) * 40 = 272,000 ft^2 = 6.24 acres.

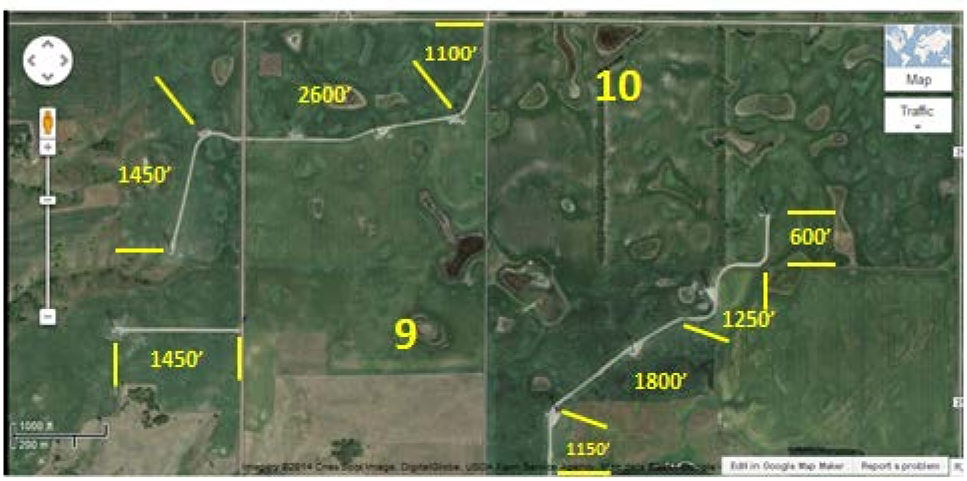
Figure 121. Ashtabula II Wind Farm Areas 5 and 6.

Ashtabula II Wind Farm, North Dakota Areas 7 & 8

Area 7 Access Roads = (1400 + 750 + 1150) * 40 = 132,000 ft^2 = 3.03 acres.
Area 8 Access Roads = (2000 + 2000 + 2100 + 2400 + 700) * 40 = 368,000 ft^2 = 8.45 acres.

Figure 122. Ashtabula II Wind Farm Areas 7 and 8.

Ashtabula II Wind Farm, North Dakota Areas 9 & 10



Area 9 Access Roads = (1450 + 1450 + 2600 + 1100) * 40 = 264,000 ft^2 = 6.06 acres.
Area 10 Access Roads = (1150 + 1800 + 1250 + 600) * 40 = 192,000 ft^2 = 4.41 acres.

Figure 123. Ashtabula II Wind Farm Areas 9 and 10.

Ashtabula II Wind Farm, North Dakota Areas 11 & 12

Area 11 Access Roads = 3100 * 40 = 124,000 ft^2 = 2.85 acres.
Area 12 Access Roads = (1000 + 2450 + 1150) * 40 = 184,000 ft^2 = 4.22 acres.

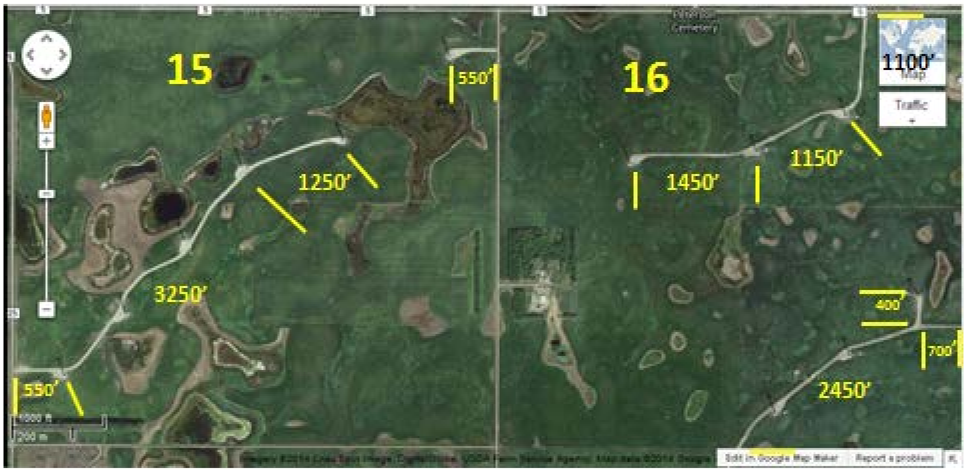
Figure 124. Ashtabula II Wind Farms Areas 11 and 12.

Ashtabula II Wind Farm, North Dakota Areas 13 & 14

Area 13 Access Roads = (1800 + 300) * 40 = 84,000 ft^2 = 1.93 acres.
Area 14 Access Roads = (1300 + 1250 + 950 + 450 + 950) * 40 = 196,000 ft^2 = 4.50 acres.

Figure 125. Ashtabula II Wind Farm Areas 13 and 14.

Ashtabula II Wind Farm, North Dakota Areas 15 & 16



Area 15 Access Roads = (550 + 3250 + 1250 + 550) * 40 = 224,000 ft^2 = 5.14 acres.
Area 16 Access Roads = (2450 + 400 + 700 + 1450 + 1150 + 1100) * 40 = 290,000 ft^2 = 6.65 acres.

Figure 126. Ashtabula II Wind Farm Areas 15 and 16.

Table 34. Ashtabula II Wind Farm Summary.

Ashtabula II Field Wind Farm, North Dakota

Name	State	No. Of Turbines	Capacity MW	Gross Total Area (acres)	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	Hectares per MW	MJ per Hectare	Transmission	Commissioned	Electricity Purchaser	Owner / Operator
Ashtabula Wind Center II	ND	80	120	10880	4403	37	36.69	98.12	230 kV	2009	Minkota Power Co. and Great River Energy	NextEra Energy

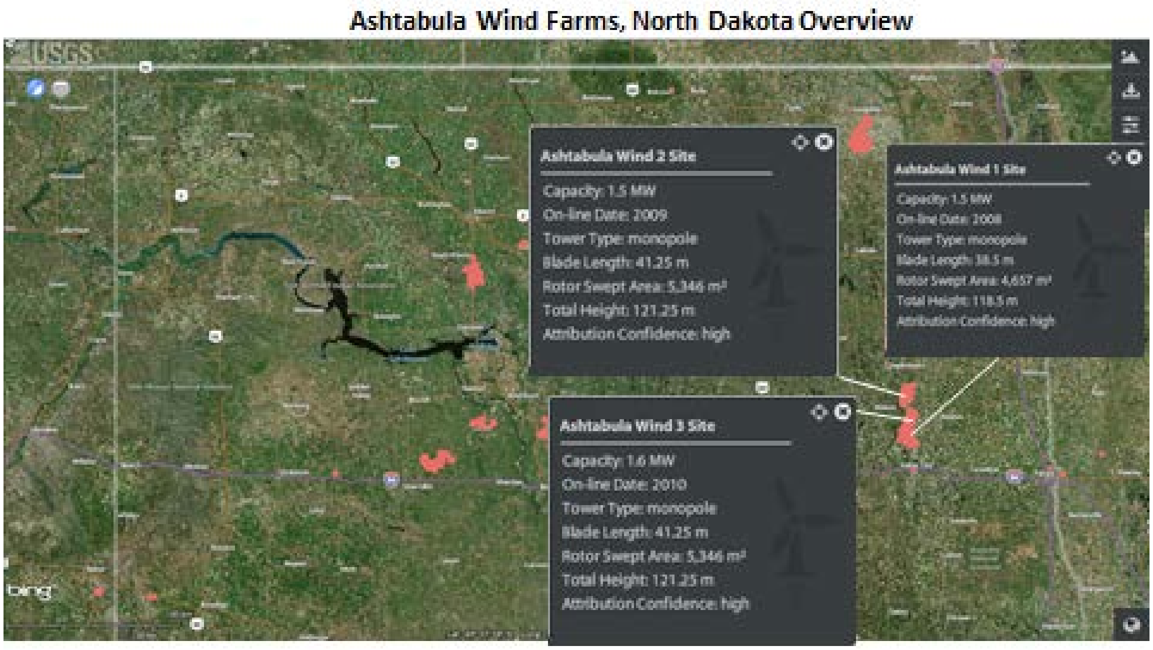
Information is based on gross area of the Wind Farm measured from Google maps.

Name	State	No. Of Turbines	Capacity MW	Actual Total Area (acres)	Actual Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	MJ per Hectare	Turbine Foundation Area (acre)	Access Roads (acre)	Substation Area (acre)	CO2 Savings metric tonnes/yr	Type of Turbine	Turbine Namplate (MW)
Ashtabula Wind Center II	ND	80	120	94	38	0.32	11393	10	84	0	Unknown	GE XLE	1.5

Using only the permanently disturbed land for the Wind Farm (access roads, substation, wind turbine foundation and structure, etc.), the MJ per Hectare increases from 498.12 to 11393 MJ per Hectare.

Appendix Q Ashtabula III Wind Farm

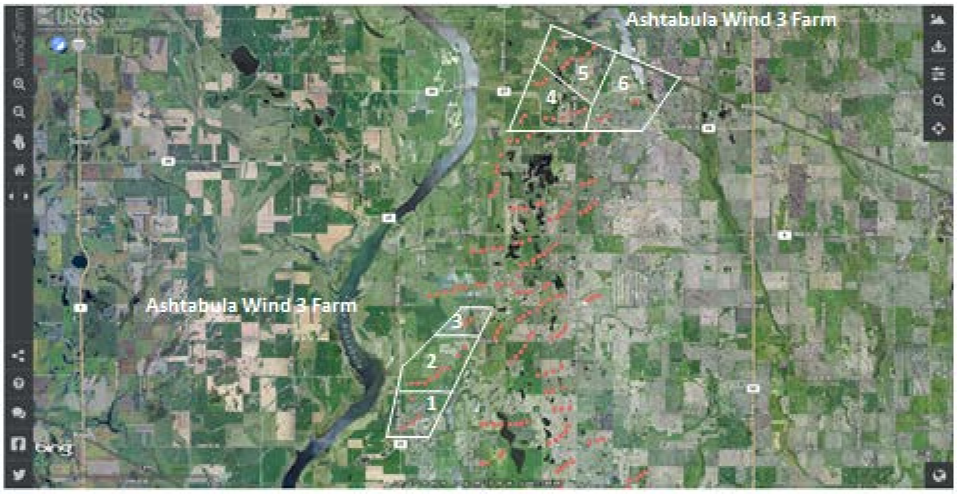
Ashtabula III Wind Farm



Reference: http://eerscmap.usgs.gov/windfarm/

Figure 127. Ashtabula III Wind Farm Overview.

Ashtabula Wind III Farm, North Dakota Overview



Reference: http://eerscmap.usgs.gov/windfarm/

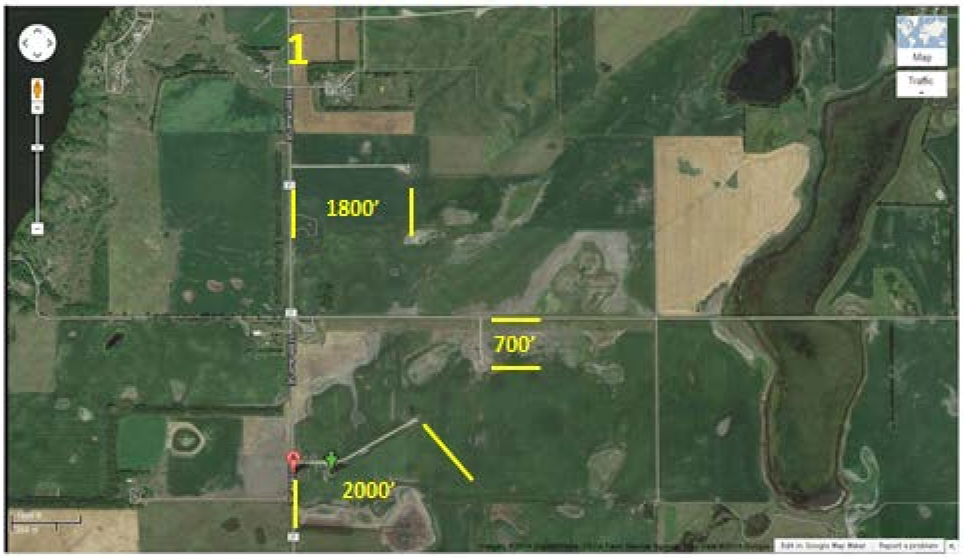
Figure 128. Ashtabula III Wind Farm with Defined Measurement Areas.

Ashtabula III Wind Farm, North Dakota Overview

Access Roads are approximately 50 feet wide.
Wind Turbine foundations are ~120 feet in diameter = 11310 ft^2 = 0.26 acre.
39 Wind Turbines * 0.26 acres each = **10.14 acres for all foundations.**

Figure 129. Ashtabula III Wind Farm Access Roads.

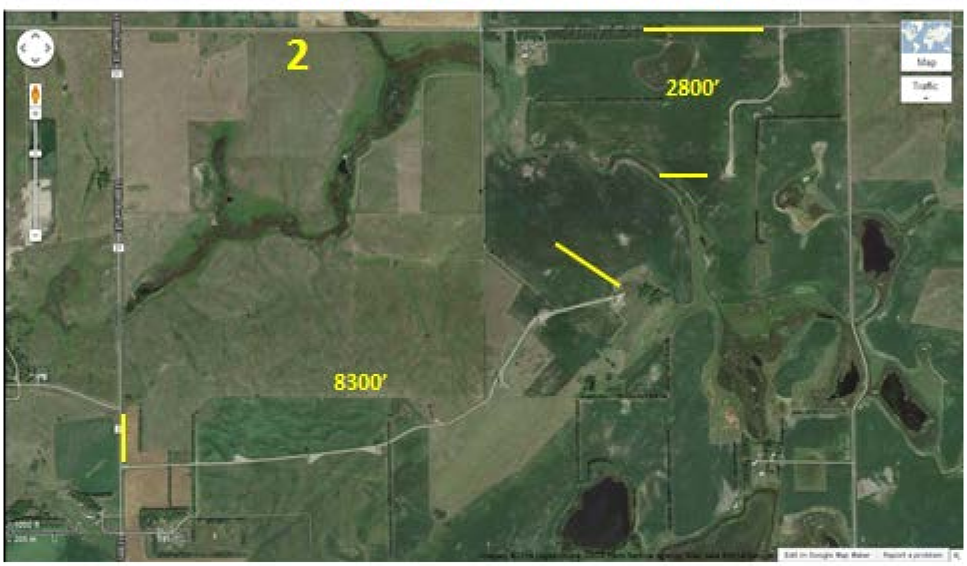
Ashtabula III Wind Farm, North Dakota Area 1



Area 1 (4 Turbines) Access Roads = (2000 + 1800 + 700) * 50 = 225,000 ft^2 = 5.17 acres.

Figure 130. Ashtabula III Wind Farm Area 1.

Ashtabula III Wind Farm, North Dakota Area 2



Area 2 (9 Turbines) Access Roads = (8300 + 2800) * 50 = 555,000 ft^2 = 12.74 acres.

Figure 131. Ashtabula III Wind Farm Area 2.

Ashtabula III Wind Farm, North Dakota Area 3

Area 3 (2 Turbines) Access Roads = 3700 * 50 = 185,000 ft² = 4.25 acres.

Figure 132. Ashtabula III Wind Farm Area 3.

Ashtabula III Wind Farm, North Dakota Area 4

Area 4 (11 Turbines) Access Roads = (2300 + 5100 + 1600 + 2400) * 50 = 570,000 ft² = 13.09 acres.

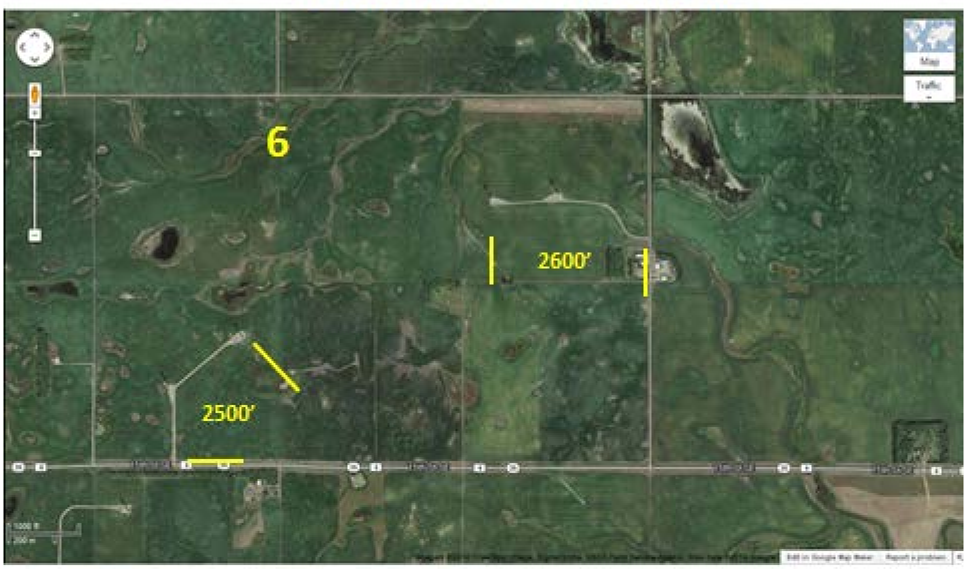
Figure 133. Ashtabula III Wind Farm Area 4.

Ashtabula III Wind Farm, North Dakota Area 5

Area 5 (9 Turbines) AccessRoads = (3600 + 2500 + 3700) * 50 = 490,000 ft^2 = 11.25 acres.

Figure 134. Ashtabula III Wind Farm Area 5.

Ashtabula III Wind Farm, North Dakota Area 6



Area 6 (4 Turbines) AccessRoads = (2500 + 2600) * 50 = 255,000 ft^2 = 5.85 acres.

Figure 135. Ashtabula III Wind Farm Area 6.

Table 35. Ashtabula III Wind Farm Summary.

Ashtabula III Field Wind Farm, North Dakota

Wind Farm Name	State	No. of Turbines	Capacity MW	Gross Total Area (acres)	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	Hectares per MW	Gross MJ per Hectare	Transmission Voltage	Commissioned	Electricity Purchaser	Owner / Operator
Ashtabula Wind Center III	ND	39	62.5	8035	3252	52	52.03	69.20	230 kV	2010	Otter Tail Power Company	NextEra Energy

Information is based on gross area of the Wind Farm measured from Google maps.

Wind Farm Name	State	No. of Turbines	Capacity MW	Actual Total Area (acres)	Permanently Disturbed (hectares)	Total Area Per Unit Capacity Hectares/MW	New MJ per Hectare	Turbine Foundation Area (acre)	Access Roads (acre)	Substation Area (acre)	CO2 Savings metric tonnes/yr	Type of Turbine	Turbine Nameplate (MW)
Ashtabula Wind Center III	ND	39	62.5	62	25	0.40	8897	10	52		Unknown	GE	1.6

Using only the permanently disturbed land for the Wind Farm (access roads, substation, wind turbine foundation and structure, etc.), the MJ per Hectare increases from 52.03 to 8897 MJ per Hectare.

Appendix R Bison Wind Farm

Bison Wind Farm

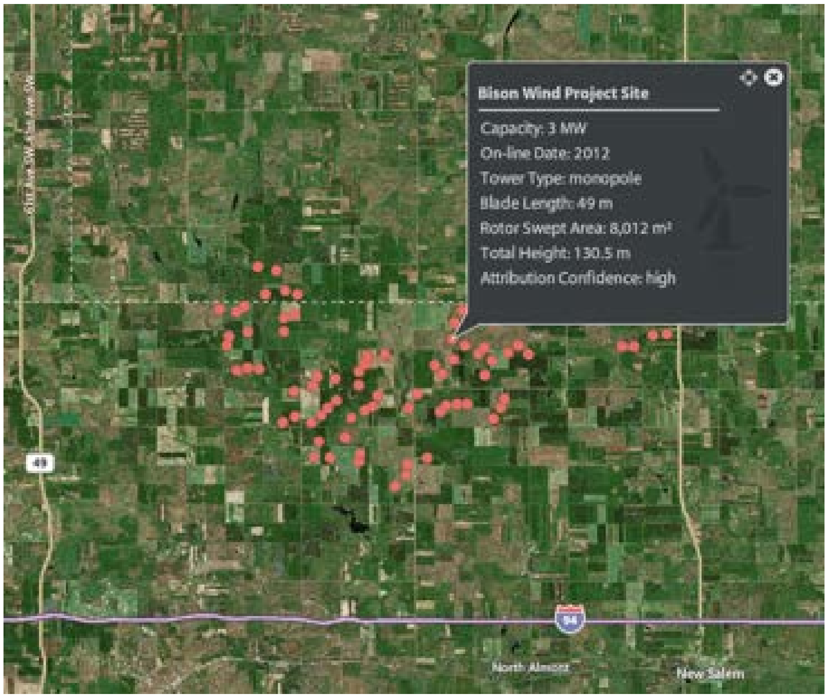
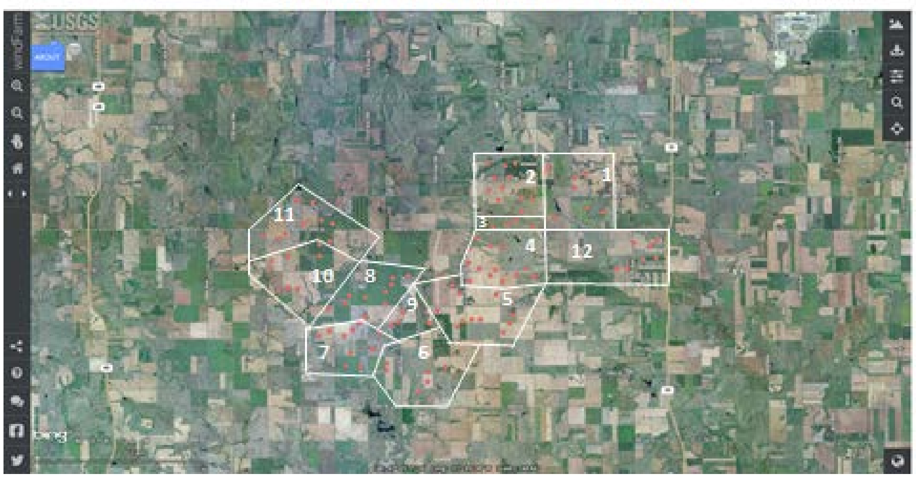


Figure 136. Bison Wind Farm Overview.

Bison Wind Farms, North Dakota Overview



Reference: http://eerscmap.usgs.gov/windfarm/

Figure 137. Bison Wind Farm with Defined Measurement Areas

Bison Wind Farm, North Dakota Overview

Access Roads are approximately 75 feet wide including right-of-way.
Wind Turbine foundations are ~180 feet in diameter = 25446 ft^2 = 0.58 acre.
58 Wind Turbines * 0.58 acres each = **33.88 acres for all foundations.**

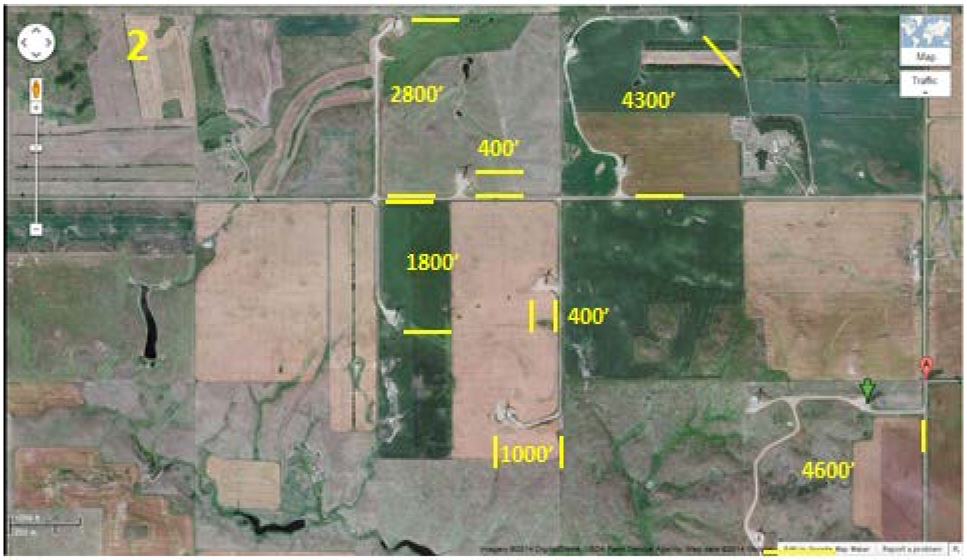
Figure 138. Bison Wind Farm Access Roads

Bison Wind Farm, North Dakota Area 1

Area 1 (8 Turbines) Access Roads = (2300 + 3100 + 5400 + 4800) * 75 = 1,170,000 ft^2 = 26.86 acres.

Figure 139. Bison Wind Farm Area 1.

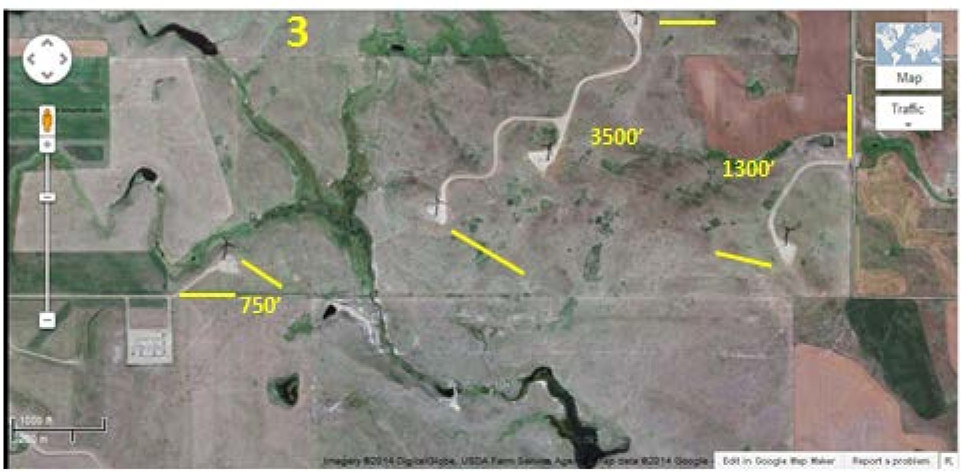
Bison Wind Farm, North Dakota Area 2



Area 2 (11 Turbines) Access Roads = (2800 + 1800 + 400 + 4300+ 400 + 1000 + 4600) * 75 = 1,147,500 ft^2 = 26.34 acres.

Figure 140. Bison Wind Farm Area 2.

Bison Wind Farm, North Dakota Area 3



Area 3 (5 Turbines) Access Roads = (750 + 3500 + 1300) * 75 = 416,250 ft^2 = 9.56 acres.

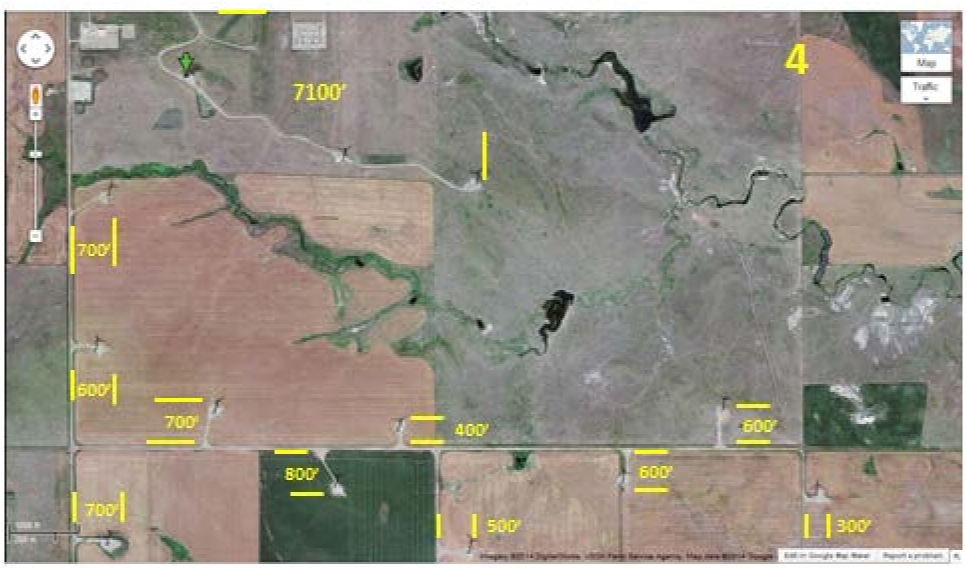
Figure 141. Bison Wind Farm Area 3.

Bison Wind Farm Substation, North Dakota

Area 3 Substation = (400 * 500) = 200,000 ft^2 = 4.59 acres.

Figure 142. Bison Wind Farm Substation.

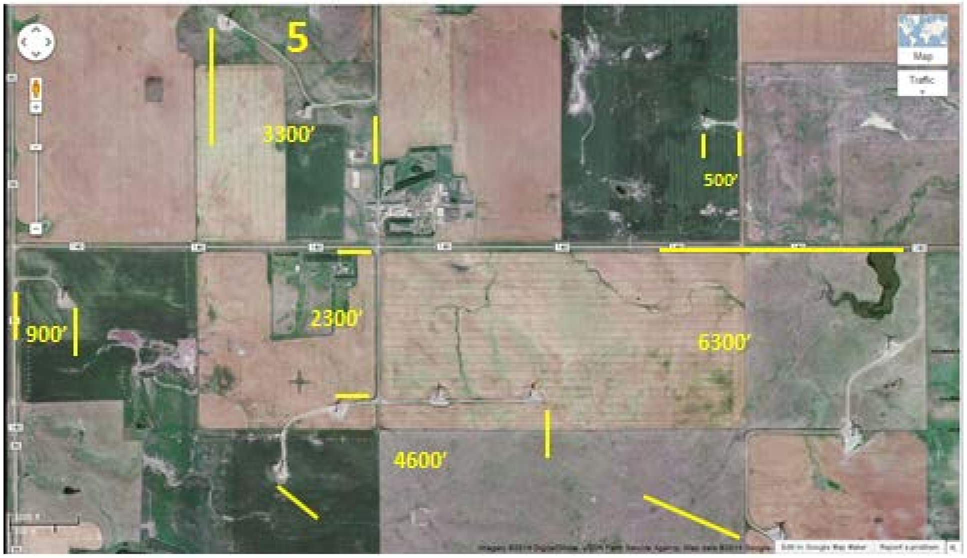
Bison Wind Farm, North Dakota Area 4



Area 4 (13 Turbines) Access Roads = (7100 + 700 + 600 + 700 + 700 + 800 + 400 + 500 + 600 + 600 + 300) * 75 = 975,000 ft^2 = 22.38 acres.

Figure 143. Bison Wind Farm Area 4.

Bison Wind Farm, North Dakota Area 5



Area 5 (11 Turbines) Access Roads = (3300 + 900 + 2300 + 4600 + 500 + 6300) * 75 = 1,342,500 ft^2 = 30.82 acres.

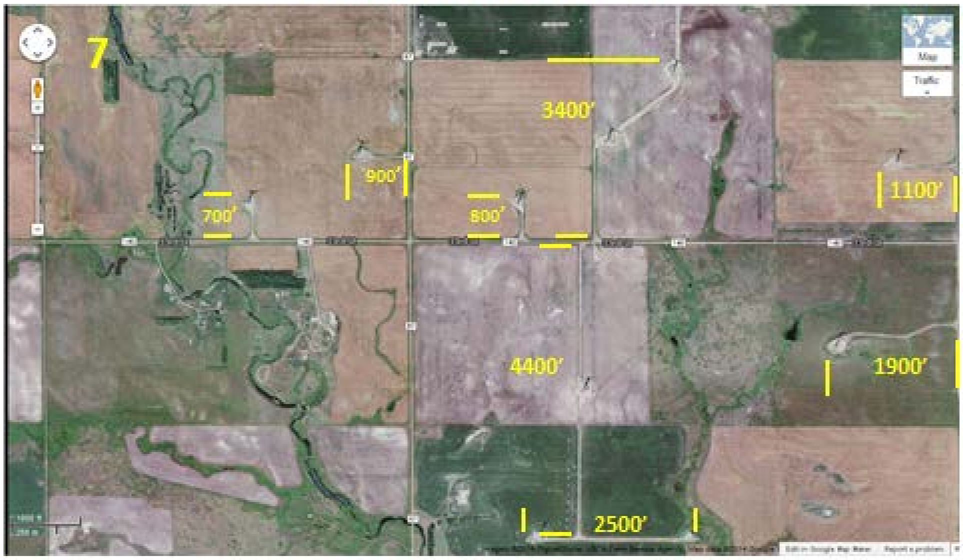
Figure 144. Bison Wind Farm Area 5.

Bison Wind Farm, North Dakota Area 6

Area 6 (6 Turbines) Access Roads = (3800 + 3900 + 3100) * 75 = 810,000 ft^2 = 18.60 acres.

Figure 145. Bison Wind Far Area 6.

Bison Wind Farm, North Dakota Area 7



Area 7 (10 Turbines) Access Roads = (700 + 900 + 800 + 3400 + 4400 + 2500 + 1900 + 1100) * 75 = 1,177,500 ft² = 27.03 acres.

Figure 146. Bison Wind Farm Area 7,

Bison Wind Farm, North Dakota Area 8

Area 8 (10 Turbines) Access Roads = (1900 + 3000 + 600 + 2700 + 8400) * 75 = 1,245,000 ft² = 28.58 acres.

Figure 147. Bison Wind Farm Area 8.

Bison Wind Farm, North Dakota Area 9

Area 9 (4 Turbines) Access Roads = (2000 + 300 + 1000) * 75 = 247,500 ft^2 = 5.68 acres.

Figure 148. Bison Wind Farm Area 9.

Bison Wind Farm, North Dakota Area 10

Area 10 (8 Turbines) Access Roads = (5600 + 3600 + 2700 + 1000 + 600) * 75 = 1,012,500 ft^2 = 23.24 acres.

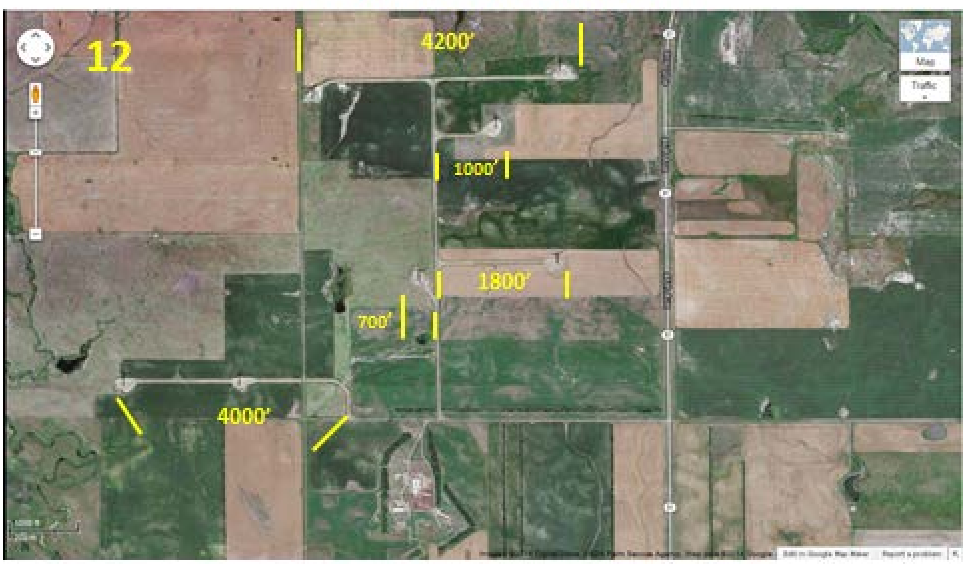
Figure 149. Bison Wind Farm Area 10.

Bison Wind Farm, North Dakota Area 11

Area 11 (9 Turbines) Access Roads = (3200 + 4400 + 5100 + 3800 + 1000 + 800 + 5500 + 700) * 75 = 1,837,500 ft^2 = 42.18 acres.

Figure 150. Bison Wind Farm Area 11.

Bison Wind Farm, North Dakota Area 12



Area 12 (7 Turbines) Access Roads = (4000 + 700 + 1800 + 1000 + 4200) * 75 = 877,500 ft^2 = 20.14 acres.

Figure 151. Bison Wind Farm Area 12.

Table 36. Bison Wind Farm Summary.

Bison Wind Farm, North Dakota

Wind Farm Name	State	No. of Turbines	Capacity MW	Gross Total Area (acres)	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	Hectares per MW	Gross MJ per Hectare	Transmission Voltage	Commissioned	Electricity Purchaser	Owner / Operator
Bison Wind Energy Center	ND	101	292.0	130000	52609	180	180.17	19.98	230 kV	2012	Minnesota Power	Minnesota Power

Information is based on gross area of the Wind Farm measured from Google maps.

Wind Farm Name	State	No. of Turbines	Capacity MW	Actual Total Area (acres)	Permanently Disturbed (hectares)	Total Area Per Unit Capacity Hectares/MW	New MJ per Hectare	Turbine Foundation Area (acre)	Access Roads (acre)	Substation Area (acre)	CO2 Savings metric tonnes/yr	Type of Turbine	Turbine Namplate (MW)
Bison Wind Energy Center	ND	101	292.0	320	129	0.44	8120	34	281	5	Unknown	Siemens	3

Using only the permanently disturbed land for the Wind Farm (access roads, substation, wind turbine foundation and structure, etc.), the MJ per Hectare increases from 180.17 to 8120 MJ per Hectare.

Appendix S Rugby Wind Farm

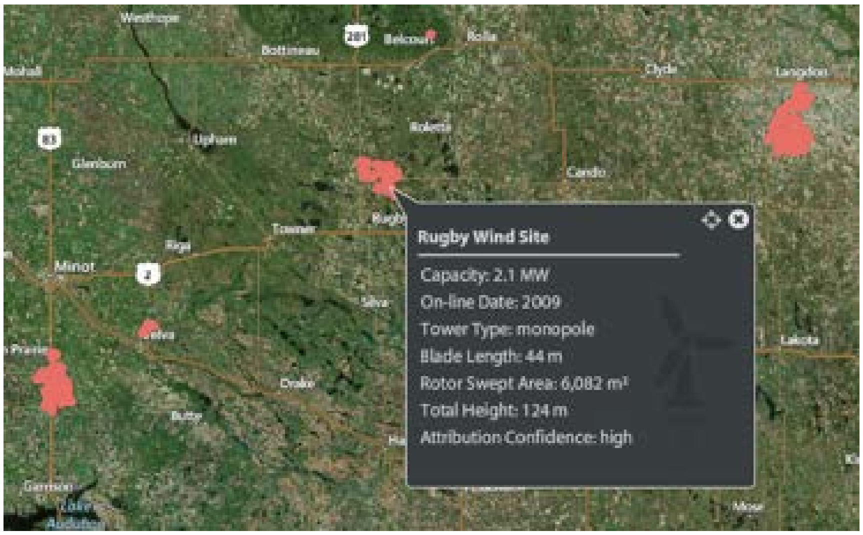


Figure 152. Rugby Wind Farm Overview

Rugby Wind Farm, North Dakota Overview

Reference: http://eerscmap.usgs.gov/windfarm/

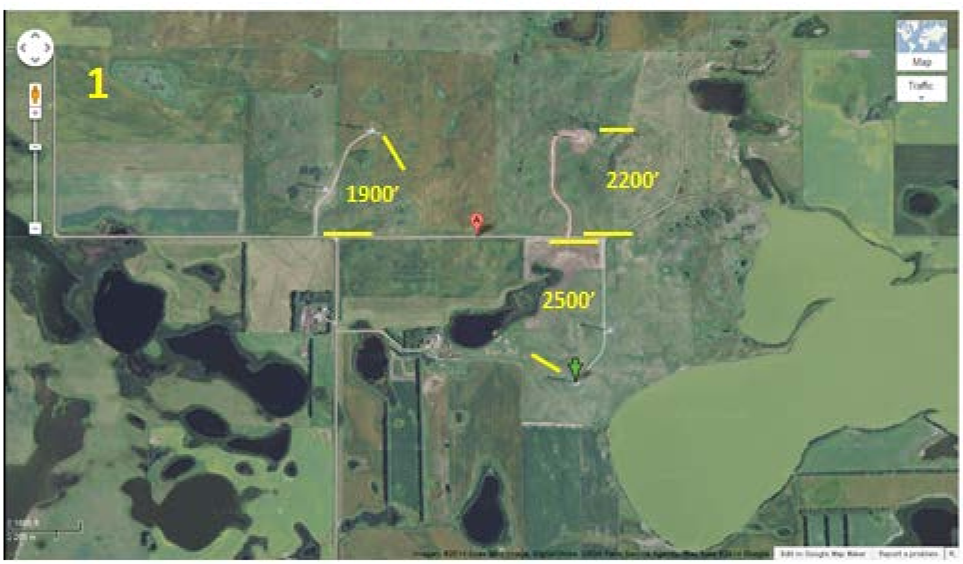
Figure 153. Rugby Wind Far with Defined Measurement Areas.

Rugby Wind Farm, North Dakota Overview

Access Roads are approximately 65 feet wide including right-of-way.
Wind Turbine foundations are ~190 feet in diameter = 28,353 ft^2 = 0.65 acre.
81Wind Turbines * 0.65 acres each = **52.65 acres for all foundations.**

Figure 154. Rugby Wind Farm Access Roads.

Rugby Wind Farm, North Dakota Area 1



Area 1 (5 Turbines) Access Roads = (1900 + 2200 + 2500) * 65 = 429,000 ft^2 = 9.85 acres.

Figure 155. Rugby Wind Farm Area 1.

Rugby Wind Farm, North Dakota Area 2

Area 2 (6 Turbines) Access Roads = (4100 + 4700) * 65 = 572,000 ft² = 13.13 acres.

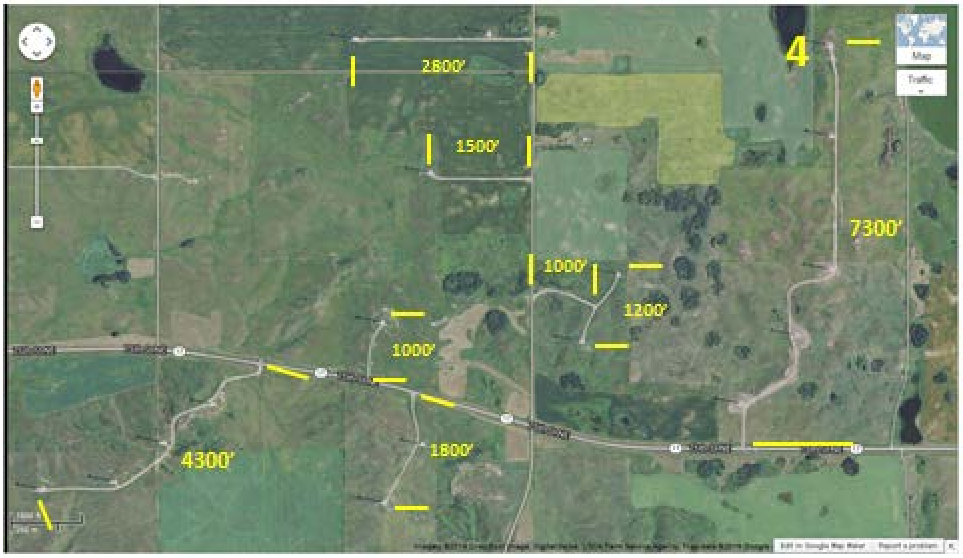
Figure 156. Rugby Wind Farm Area 2.

Rugby Wind Farm, North Dakota Area 3

Area 3 (6 Turbines) Access Roads = (4500 + 2900) * 65 = 481,000 ft² = 11.04 acres.

Figure 157. Rugby Wind Farm Area 3.

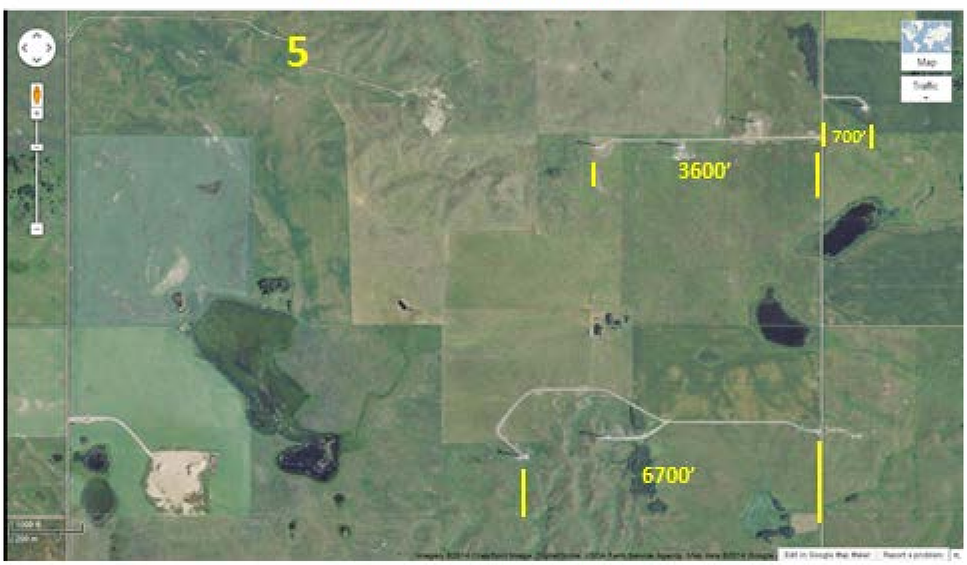
Rugby Wind Farm, North Dakota Area 4



Area 4 (16 Turbines) Access Roads = (4300 + 1000 + 1800 + 1000 + 1200 + 1500 + 2800 +7300) * 65 = 1,358,500 ft² = 31.19 acres.

Figure 158. Rugby Wind Farm Area 4.

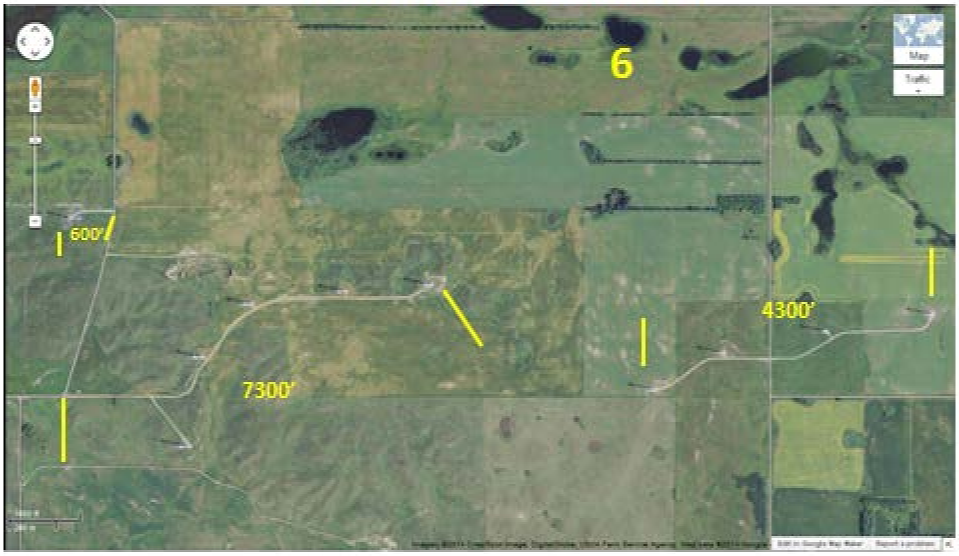
Rugby Wind Farm, North Dakota Area 5



Area 5 (6 Turbines) Access Roads = (3600 + 700 + 6700) * 65 = 715,000 ft² = 16.41 acres.

Figure 159. Rugby Wind Far Area 5.

Rugby Wind Farm, North Dakota Area 6



Area 6 (10 Turbines) Access Roads = (600 + 7300 + 4300) * 65 = 793,000 ft^2 = 18.20 acres.

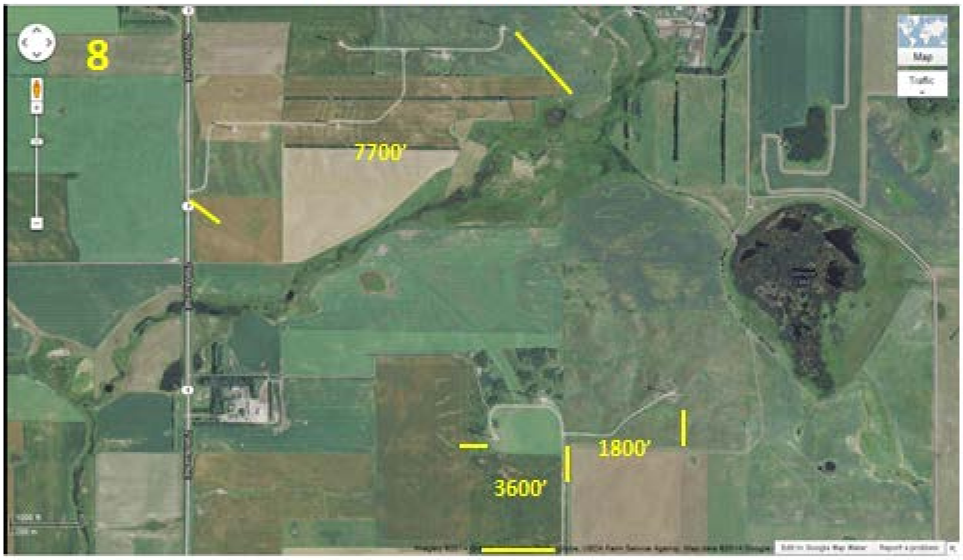
Figure 160. Rugby Wind Farm Area 6.

Rugby Wind Farm, North Dakota Area 7

Area 7 (6 Turbines) Access Roads = 8100 * 65 = 526,500 ft^2 = 12.09 acres.

Figure 161. Rugby Wind Farm Area 7.

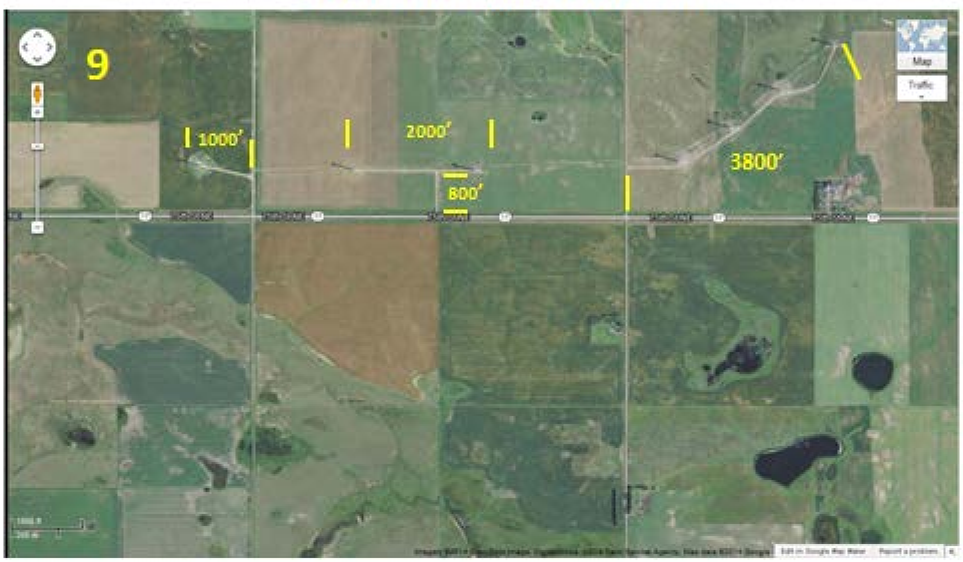
Rugby Wind Farm, North Dakota Area 8



Area 8 (8 Turbines) Access Roads = (7700 + 3700 + 1800) * 65 = 858,000 ft^2 = 19.70 acres.

Figure 162. Rugby Wind Farm Area 8.

Rugby Wind Farm, North Dakota Area 9



Area 9 (7 Turbines) Access Roads = (1000 + 2000 + 800 + 3800) * 65 = 494,000 ft^2 = 11.34 acres.

Figure 163. Rugby Wind Farm Area 9.

Table 37. Rugby Wind Farm Summary.

Wind Farm Name	State	No. of Turbines	Capacity MW	Gross Total Area (acres)	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	Hectares per MW	Gross MJ per Hectare	Transmission Voltage	Commissioned	Electricity Purchaser	Owner / Operator
Rugby Wind Power	ND	71	149.1	9554	3866	26	25.93	138.83	230 kV	2009	Missouri River Energy Services	Iberdrola Renewables, LLC

Information is based on gross area of the Wind Farm measured from Google maps.

Wind Farm Name	State	No. of Turbines	Capacity MW	Actual Total Area (acres)	Permanently Disturbed (hectares)	Total Area Per Unit Capacity Hectares/MW	New MJ per Hectare	Electricity Purchaser	Owner / Operator	Turbine Foundation Area (acre)	Access Roads (acre)	Substation Area (acre)	CO2 Savings metric tonnes/yr	Type of Turbine	Turbine Nameplate (MW)
Rugby Wind Power	ND	71	149.1	185	75	0.50	7187	Missouri River Energy Services	Iberdrola Renewables, LLC	53	132		Unknown	Suzlon S88	2.1

Using only the permanently disturbed land for the Wind Farm (access roads, substation, wind turbine foundation and structure, etc.), the MJ per Hectare increases from 138.83 to 7187 MJ per Hectare.

Appendix T Prairie Winds Wind Farm

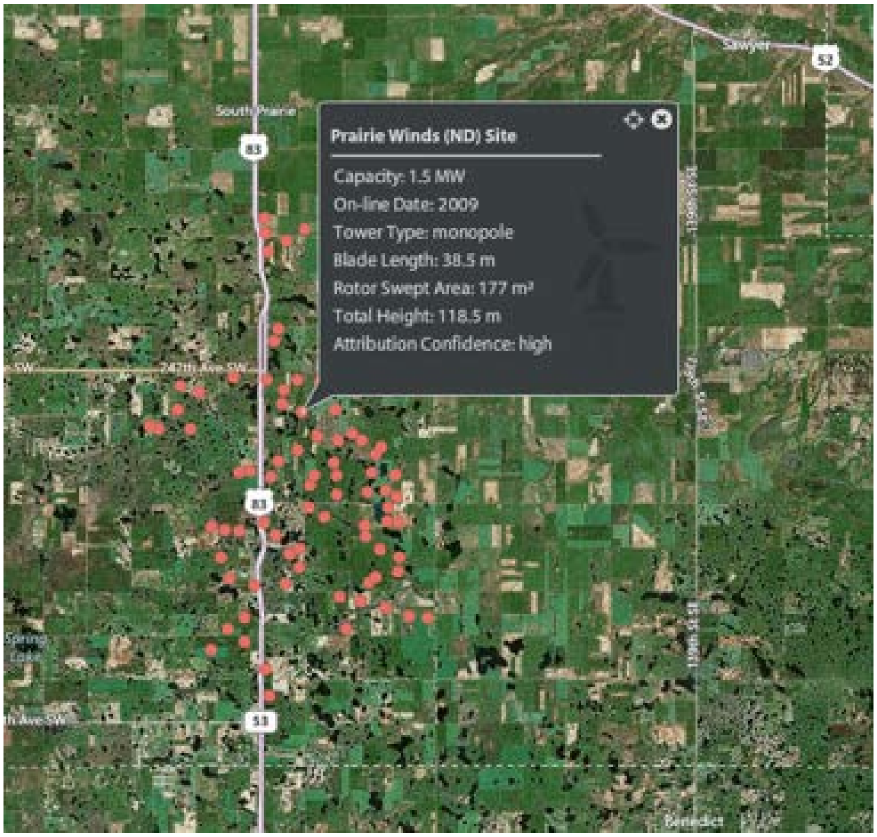
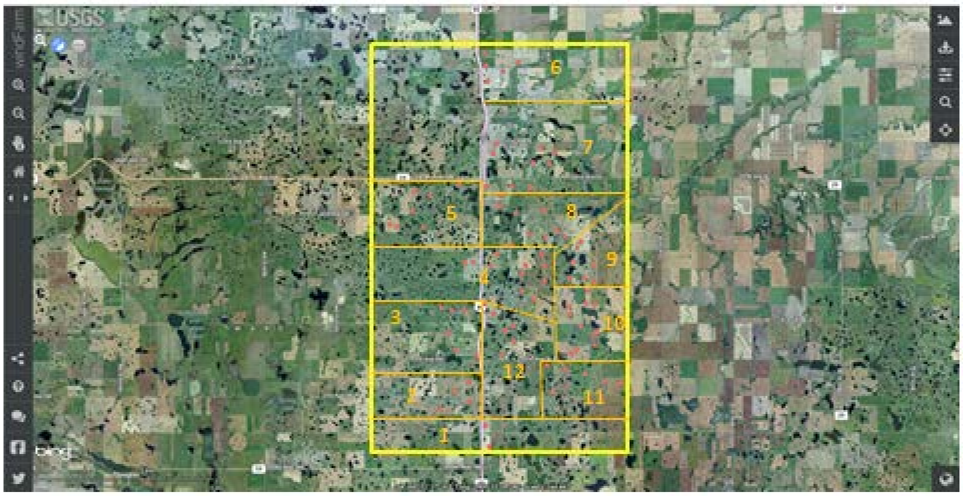


Figure 164. Prairie Winds Wind Farm Overview.

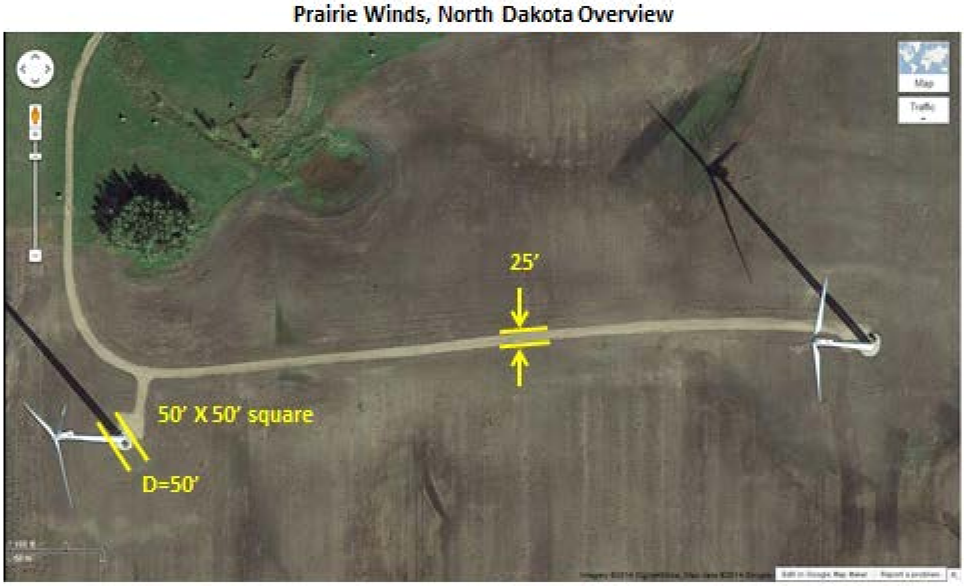
Prairie Winds, North Dakota Area Overview



Reference: http://eerscmap.usgs.gov/windfarm/

Figure 165. Prairie Winds Wind Farm with Defined Measurement Areas.

Prairie Winds, North Dakota Overview



Access Roads are approximately 25 feet wide.
Wind Turbine foundations are 50 feet in diameter = 1963 ft^2 = 0.05 acre plus a 12,500 ft^2 = 0.29 acre square area for a total of 0.34 acre per turbine.
77 Wind Turbines * 0.34 acres each = **26.18 acres for all foundations.**

Figure 166. Prairie Winds Wind Farm Access Roads.

Prairie Wind, North Dakota Area 1

Area 1 (2 Turbines) Access Roads = (1600 + 1400) * 25 = 75,000 ft^2 = 1.72 acres.

Figure 167. Prairie Winds Wind Farm Area 1.

Prairie Wind, North Dakota Area 2

Area 2 (4 Turbines) Access Roads = (1800 + 1300 + 2900 + 900) * 25 = 172,500 ft^2 = 3.96 acres.

Figure 168. Prairie Winds Wind Farm Area 2.

Prairie Wind, North Dakota Area 3

Area 3 (6 Turbines) Access Roads = (3800 + 2500 + 2200 + 1600 + 3500 + 800) * 25 = 360,000 ft^2 = 8.26 acres.

Figure 169. Prairie Winds Wind Farm Area 3.

Prairie Wind, North Dakota Substation

Substation Area = (220 * 340) + (400 * 75) = 104,800 ft^2 = 2.41 acres.

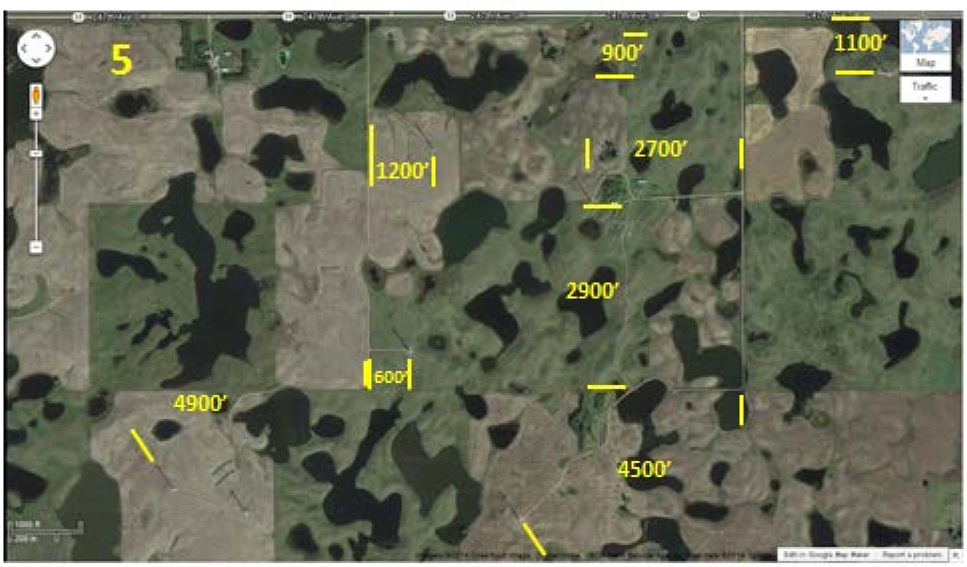
Figure 170. Prairie Winds Wind Farm Substation.

Prairie Wind, North Dakota Area 4

Area 4 (11 Turbines) Access Roads = (1900 + 1300 + 2900 + 1800 + 3600 + 5100 + 700 + 2100) * 25 = 485,000 ft^2 = 11.13 acres.

Figure 171. Prairie Winds Wind Farm Area 4.

Prairie Wind, North Dakota Area 5



Area 5 (7 Turbines) Access Roads = (4900 + 600 + 1200 + 900 + 2700 + 2900 + 4500 + 1100) * 25 = 470,000 ft^2 = 10.79 acres.

Figure 172. Prairie Winds Wind Farm Area 5.

Prairie Wind, North Dakota Area 6

Area 6 (4 Turbines) Access Roads = (1300 + 500 + 900 + 800) * 25 = 87,500 ft^2 = 2.01 acres.

Figure 173. Prairie Winds Wind Farm Area 6.

Prairie Wind, North Dakota Area 7

Area 7 (9 Turbines) Access Roads = (400 + 2100 + 1900 + 900 + 1000 + 3400 + 2000) * 25 = 292,500 ft^2 = 6.71 acres.

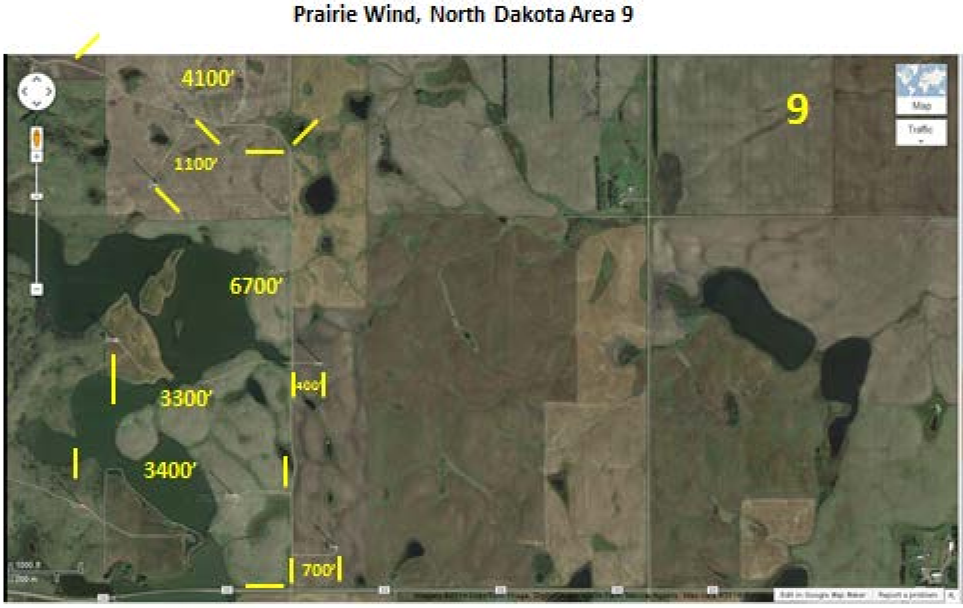
Figure 174. Prairie Winds Wind Farn Area 7.

Prairie Wind, North Dakota Area 8

Area 8 (9 Turbines) Access Roads = (2300 + 2800 + 5900 + 8200 + 600 + 2000) * 25 = 545,000 ft^2 = 12.51 acres.

Figure 175. Prairie Winds Wind Farm Area 8.

Prairie Wind, North Dakota Area 9



Area 9 (7 Turbines) Access Roads = (4100 + 1100 + 6700 + 3300 + 3400 + 400 + 700) * 25 = 492,500 ft^2 = 11.31 acres.

Figure 176. Prairie Winds Wind Farm Area 9.

Prairie Wind, North Dakota Area 10

Area 10 (10 Turbines) Access Roads = (600 + 700 + 1800 + 2900 + 700 + 2900 + 1600 + 3400) * 25 = 365,000 ft^2 = 8.38 acres.

Figure 177. Prairie Winds Wind Farm Area 10.

Prairie Wind, North Dakota Area 11

Area 11 (6 Turbines) Access Roads = (1200 + 300 + 1200 + 2300 + 900 + 2800 + 800) * 25 = 237,500 ft^2 = 5.45 acres.

Figure 178. Prairie Winds Wind Farm Area 11.

Prairie Wind, North Dakota Area 12

Area 12 (6 Turbines) Access Roads = (700 + 1500 + 2100 + 3300 + 800 + 1000) * 25 = 235,000 ft^2 = 5.39 acres.

Figure 179. Prairie Winds Wind Farm Area 12.

Table 38. Prairie Winds Wind Farm Summary.

Prairie Winds, North Dakota

Name	State	No. Of Turbines	Capacity MW	Gross Total Area (acres)	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	Hectares per MW	MJ per Hectare	Transmission	Commissioned	Electricity Purchaser	Owner / Operator
Prarie Winds	ND	77	115.5	30000	12141	105	105.11	34.25	Unknown	2009	Unknown	Basin Electric

Information is based on gross area of the Wind Farm measured from Google maps.

Name	State	No. Of Turbines	Capacity MW	Actual Total Area (acres)	Actual Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	MJ per Hectare	Electricity Purchaser	Owner / Operator	Turbine Foundation Area (acre)	Access Roads (acre)	Substation Area (acre)	Turbine Height (ft)	CO2 Savings metric tonnes/yr	Type of Turbine	Turbine Namplate (MW)
Prarie Winds	ND	77	115.5	116	47	0.41	8841	Unknown	Basin Electric	26	88	2		Unknown	Nordex	2.6

Using only the permanently disturbed land for the Wind Farm (access roads, substation, wind turbine foundation and structure, etc.), the MJ per Hectare increases from 34.25 to 8841 MJ per Hectare.

Appendix U Baldwin Wind Farm

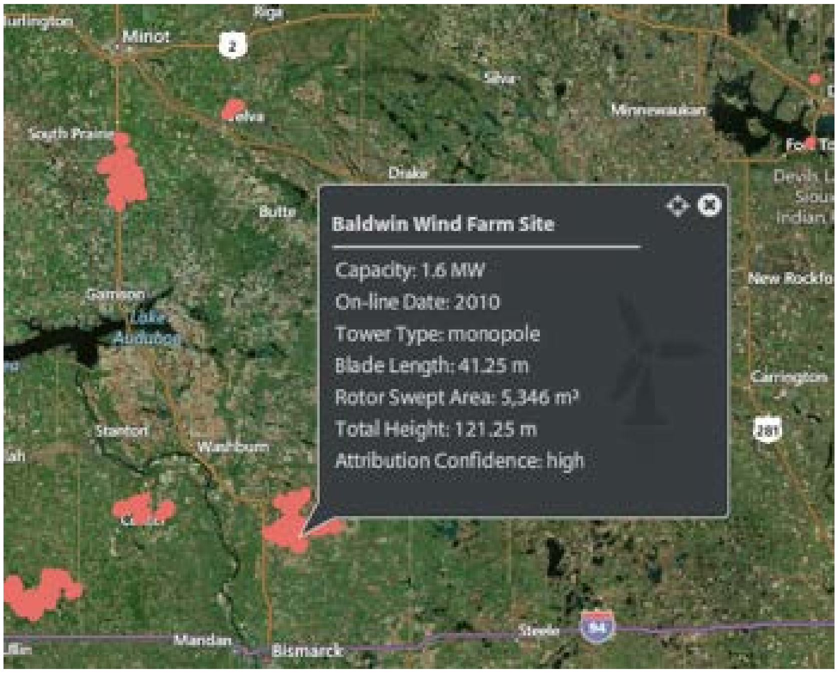
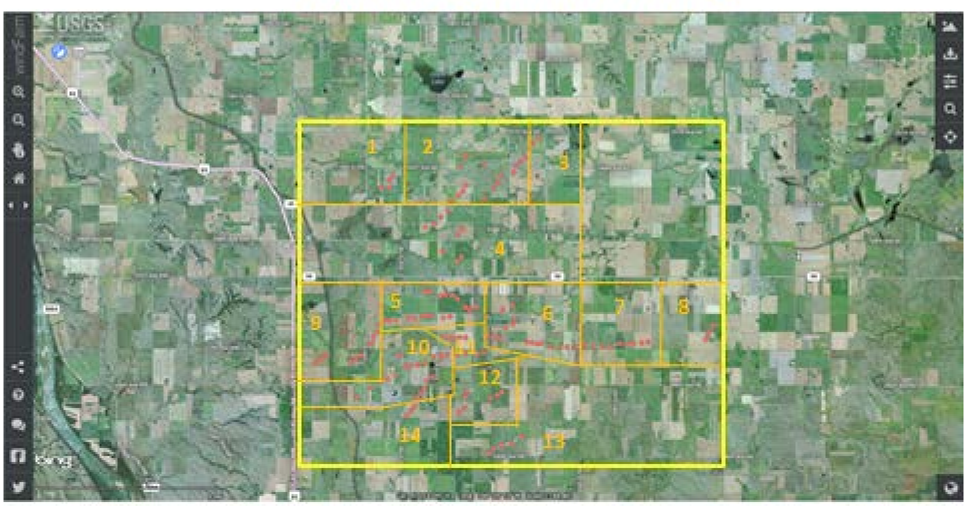


Figure 180. Baldwin Wind Farm Overview.

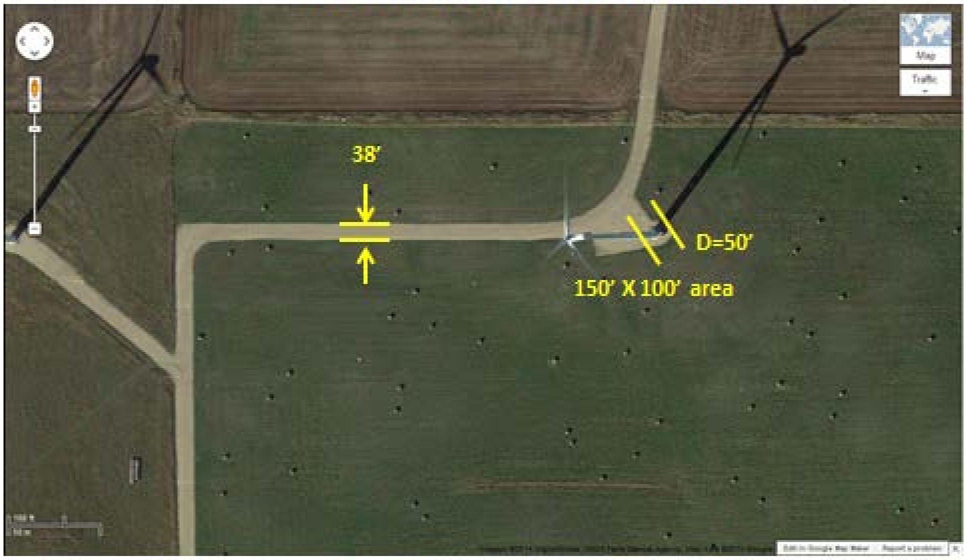
Baldwin Wind Farm, North Dakota Overview



Reference: http://eerscmap.usgs.gov/windfarm/

Figure 181. Baldwin Wind Farm with Defined Measurement Areas.

Baldwin Wind Farm, North Dakota Overview



Access Roads are approximately 38 feet wide.
Wind Turbine foundations are 50 feet in diameter = 1963 ft^2 = 0.05 acre plus a 15,000 ft^2 = 0.34 acre square area for a total of 0.39 acre per turbine.
66 Wind Turbines * 0.39 acres each = **25.74 acres for all foundations.**

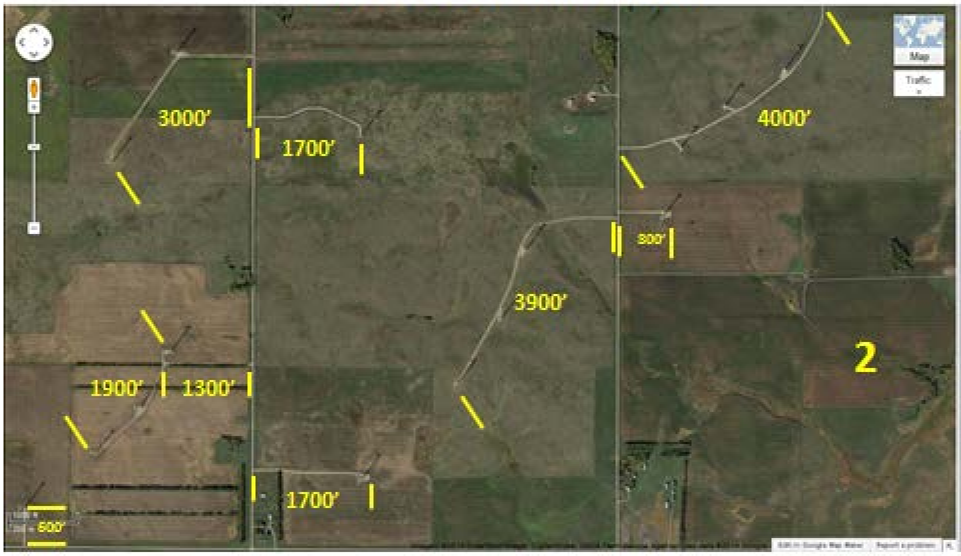
Figure 182. Baldwin Wind Farm Access Roads.

Baldwin Wind Farm, North Dakota Area 1

Area 1 (4 Turbines) Access Roads = 5900 * 38 = 224,200 ft^2 = 5.15 acres.

Figure 183. Baldwin Wind Farm Area 1.

Baldwin Wind Farm, North Dakota Area 2



Area 2 (15Turbines) Access Roads = (3000 + 1900 + 600 + 1300 + 1700 + 3900 + 800 + 4000) * 38 = 653,600 ft^2 = 15.00 acres.

Figure 184. Baldwin Wind Farm Area 2.

Baldwin Wind Farm, North Dakota Area 3

Area 3 (3 Turbines) Access Roads = (2300 + 800) * 38 = 117,800 ft^2 = 2.70 acres.

Figure 185. Baldwin Wind Farm Area 3.

Baldwin Wind Farm, North Dakota Substation

Substation Area = (800 * 800) = 640,000 ft^2 = 14.69 acres.

Figure 186. Baldwin Wind Farm Substation.

Baldwin Wind Farm, North Dakota Area 4

Area 4 (9 Turbines) Access Roads = (900 + 500 + 1900 + 1800 + 2700 + 3000) * 38 = 410,400 ft^2 = 9.42 acres.

Figure 187. Baldwin Wind Farm Area 4.

Baldwin Wind Farm, North Dakota Area 5

Area 5 (19 Turbines) Access Roads = (8000 + 1900 + 3600 + 1800 + 1600 + 500) * 38 = 661,200 ft^2 = 15.18 acres.

Figure 188. Baldwin Wind Farm Area 5.

Baldwin Wind Farm, North Dakota Area 6

Area 6 (16 Turbines) Access Roads = (1000 + 500 + 2300 + 2000 + 2700 + 5600) * 38 = 535,800 ft^2 = 12.30 acres.

Figure 189. Baldwin Wind Farm Area 6.

Baldwin Wind Farm, North Dakota Area 7

Area 7 (9 Turbines) Access Roads = 11,200 * 38 = 425,600 ft^2 = 9.77 acres.

Figure 190. Baldwin Wind Farm Area 7.

Baldwin Wind Farm, North Dakota Area 8

Area 8 (3 Turbines) Access Roads = 4100 * 38 = 155,800 ft^2 = 3.58 acres.

Figure 191. Baldwin Wind Farm Area 8.

Baldwin Wind Farm, North Dakota Area 9

Area 9 (10 Turbines) Access Roads = (4700 + 2800 + 4400) * 38 = 452,200 ft^2 = 10.38 acres.

Figure 192. Baldwin Wind Farm Area 9.

Baldwin Wind Farm, North Dakota Area 10

Area 10 (18 Turbines) Access Roads = (1300 + 500 + 3000 + 400 + 2500 + 4800 + 2200 + 1700) * 38 = 623,200 ft^2 = 14.31 acres.

Figure 193. Baldwin Wind Farm Area 10.

Baldwin Wind Farm, North Dakota Area 11

Area 11 (9 Turbines) Access Roads = (4600 + 4200) * 38 = 334,400 ft^2 = 7.68 acres.

Figure 194. Baldwin Wind Farm Area 11.

Baldwin Wind Farm, North Dakota Area 12

Area 12 (7 Turbines) Access Roads = (2800 + 1400 + 1000 + 3100) * 38 = 315,400 ft^2 = 7.24 acres.

Figure 195. Baldwin Wind Farm Area 12.

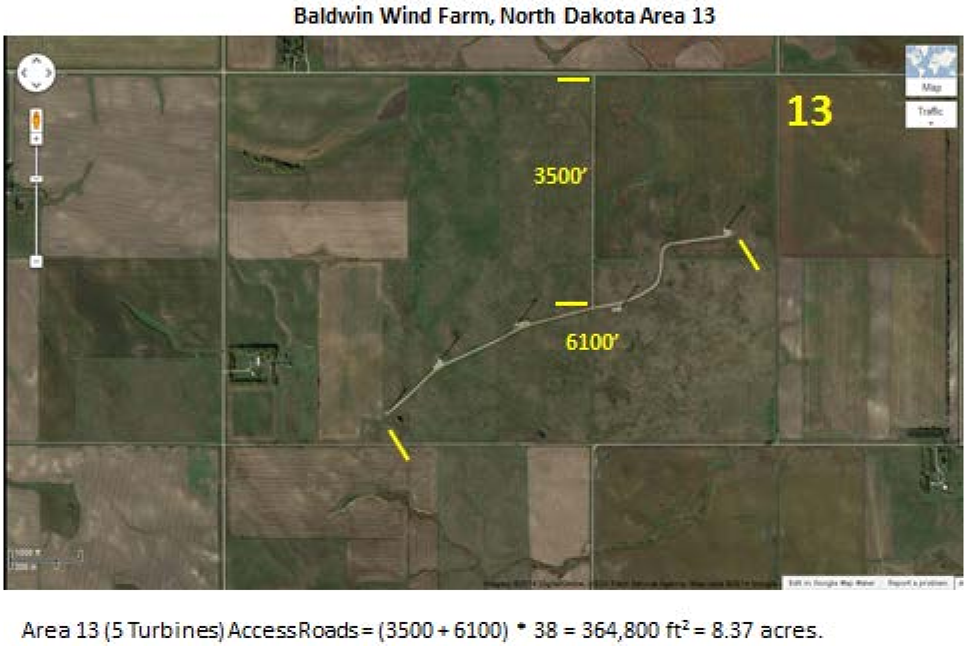


Figure 196. Baldwin Wind Farm Area 13.

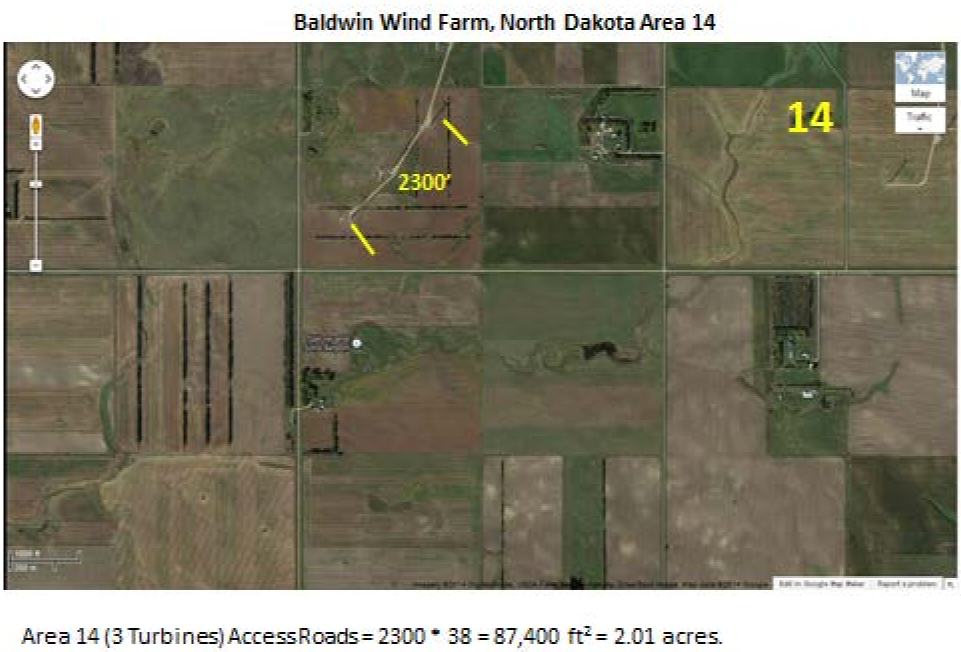


Figure 197. Baldwin Wind Farm Area 14.

Table 39. Baldwin Wind Farm Summary

Baldwin Wind Farm, North Dakota

Name	State	No. Of Turbines	Capacity MW	Gross Total Area (acres)	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	Hectares per MW	MJ per Hectare	Transmission	Commissioned	Electricity Purchaser	Owner / Operator
Baldwin Wind Farm	ND	66	102.4	21218	8587	84	83.85	42.93	34.5 kV	2010	Basin Electric Power	NextEra Energy

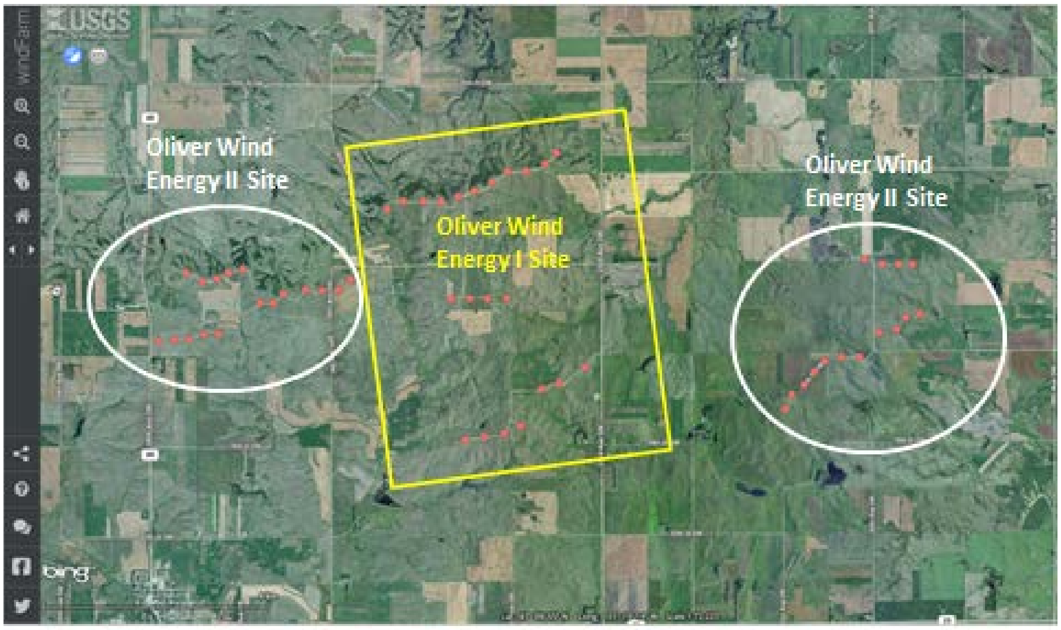
Information is based on gross area of the Wind Farm measured from Google maps.

Name	State	No. Of Turbines	Capacity MW	Actual Total Area (acres)	Actual Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	MJ per Hectare	Turbine Foundation Area (acre)	Access Roads (acre)	Substation Area (acre)	Turbine Height (ft)	CO2 Savings metric tonnes/yr	Type of Turbine	Turbine Namplate (MW)
Baldwin Wind Farm	ND	66	102.4	164	66	0.65	5571	26	123	15	262	Unknown	GE XLE	1.6

Using only the permanently disturbed land for the Wind Farm (access roads, substation, wind turbine foundation and structure, etc.), the MJ per Hectare increases from 42.93 to 5571 MJ per Hectare.

Appendix V Oliver Wind Energy I Wind Farm

Oliver Wind Energy, North Dakota Overview



Reference: http://eerscmap.usgs.gov/windfarm/

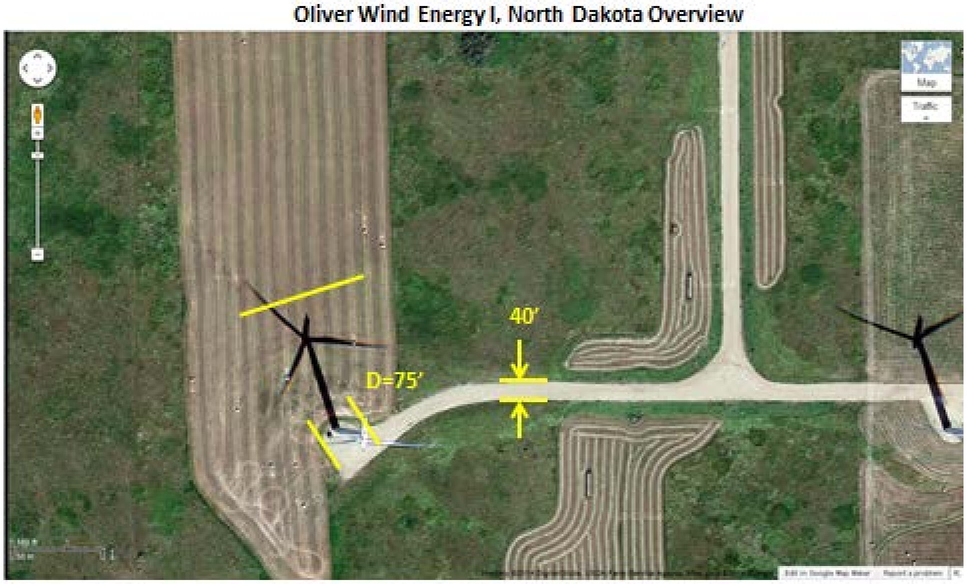
Figure 198. Olive Wind Energy I Wind Farm Overview.

Oliver Wind Energy I, North Dakota Overview

Oliver Wind Energy I, North Dakota Coordinates: 47.180446°, -101.225116°
Address: 1851 33RD AVE SW, CENTER, ND, 58530-9486 (Reference Point A)
Area = 13,860 ft. X 21,780 ft. = 301,870,800 ft² = 6930 acres.

Figure 199. Oliver Wind Energy I Wind Farm with Defined Measurement Areas.

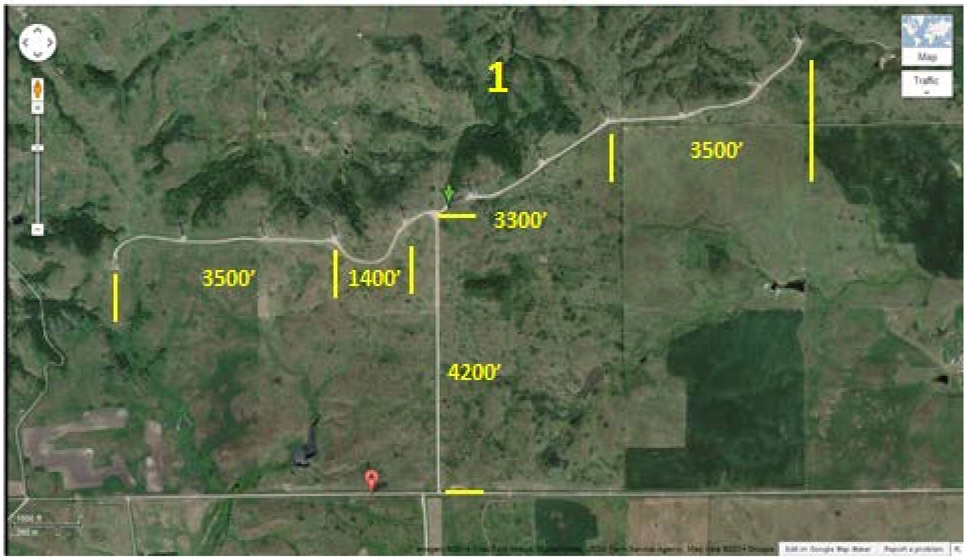
Oliver Wind Energy I, North Dakota Overview



Access Roads are approximately 40 feet wide.
Wind Turbine foundations are 75 feet in diameter = 4418 ft² = 0.10 acre.
22 Wind Turbines * 0.10 acres each = **2.2 acres for all foundations.**

Figure 200. Oliver Wind Energy I Wind Farm Access Roads.

Oliver Wind Energy I, North Dakota Area 1



Area 1 Access Roads = (3500 + 1400 + 3300 + 3500 + 4200) * 40 = 636,000 ft^2 = 14.60 acres.

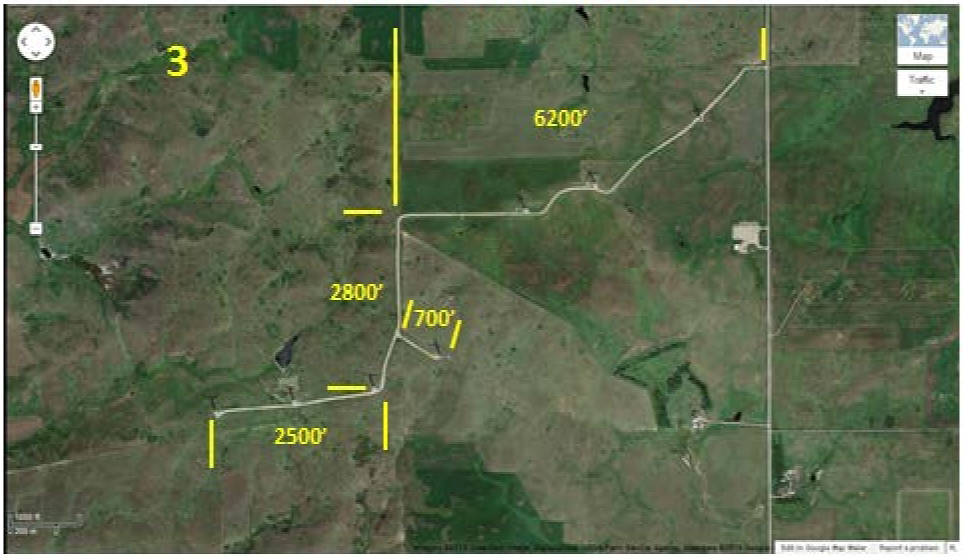
Figure 201. Oliver Wind Energy I Wind Farm Area 1.

Oliver Wind Energy I, North Dakota Area 2

Area 2 Access Roads = (1950 + 1950 + 1500 + 450) * 40 = 234,000 ft^2 = 5.37 acres.

Figure 202. Oliver Wind Energy I Wind Farm Area 2

Oliver Wind Energy I, North Dakota Area 3



Area 3 Access Roads = (2500 + 2800 + 700 + 6200) * 40 = 488,000 ft^2 = 11.20 acres.

Figure 203. Oliver Wind Energy I Wind Farm Area 3.

Table 40. Oliver Wind Energy I Wind Farm Summary.

Oliver Wind Energy I, North Dakota

Name	State	No. Of Turbines	Capacity MW	Gross Total Area (acres)	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	Hectares per MW	MJ per Hectare	Transmission	Commissioned	Electricity Purchaser	Owner / Operator
Oliver Wind Energy I	ND	22	50.6	6930	2804	55	55.42	64.95	Unknown	2006	FPL Energy	NextEra Energy

Information is based on gross area of the Wind Farm measured from Google maps.

Name	State	No. Of Turbines	Capacity MW	Actual Total Area (acres)	Actual Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	MJ per Hectare	Electricity Purchaser	Owner / Operator	Turbine Foundation Area (acre)	Access Roads (acre)	Substation Area (acre)	Turbine Height (ft)	CO2 Savings	Type of Turbine	Turbine Namplate (MW)
Oliver Wind Energy I	ND	22	50.6	33	14	0.27	13489	FPL Energy	NextEra Energy	2	31	0	262	Unknown	Siemens	2.3

Using only the permanently disturbed land for the Wind Farm (access roads, substation, wind turbine foundation and structure, etc.), the MJ per Hectare increases from 64.95 to 13489 MJ per Hectare.

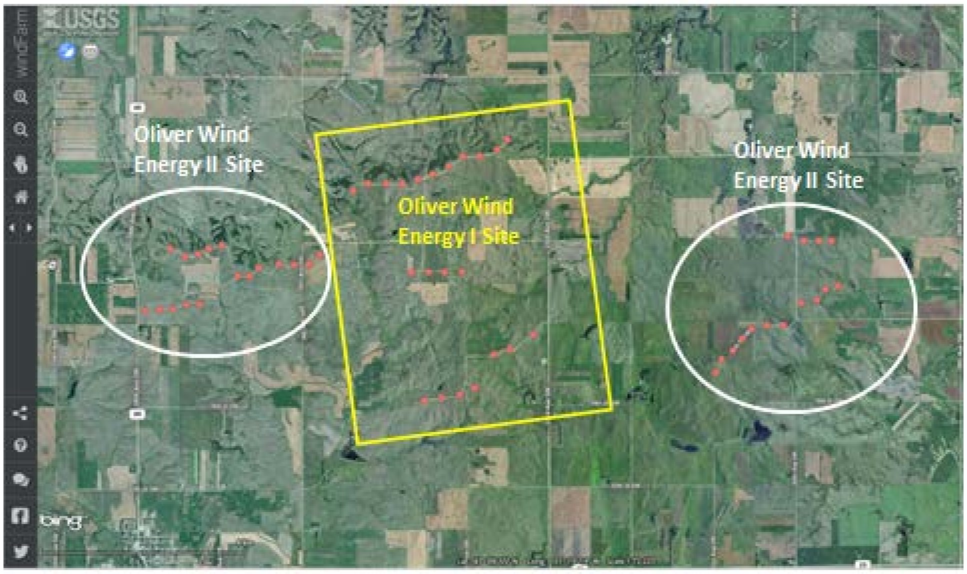
Appendix W Oliver Wind Energy II Wind Farm

Oliver Wind Energy II, North Dakota Overview

Reference:
http://eerscmap.usgs.gov/windfarm/

Figure 204. Oliver Wind Energy II Wind Farm Overview.

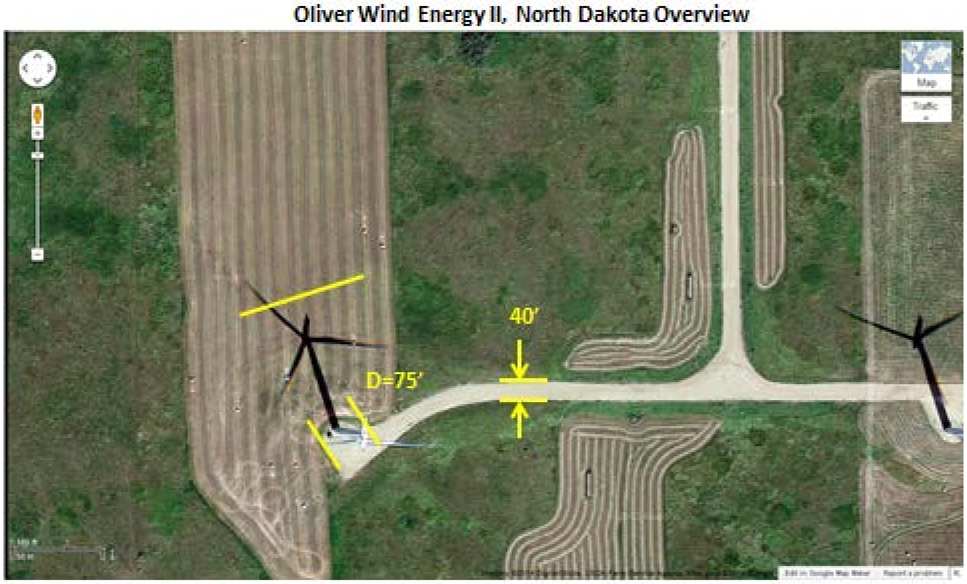
Oliver Wind Energy, North Dakota Overview



Reference: http://eerscmap.usgs.gov/windfarm/

Figure 205. Oliver Wind Energy II Wind Farm with Defined Measurement Areas.

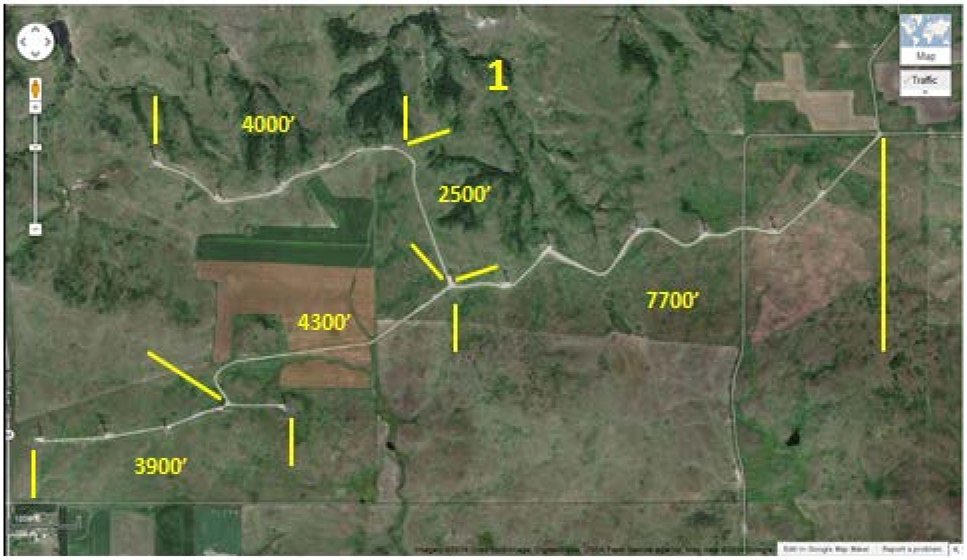
Oliver Wind Energy II, North Dakota Overview



Access Roads are approximately 40 feet wide.
Wind Turbine foundations are 75 feet in diameter = 4418 ft^2 = 0.10 acre.
32 Wind Turbines * 0.10 acres each = **3.2 acres for all foundations.**

Figure 206. Oliver Wind Energy II Wind Farm Access Roads.

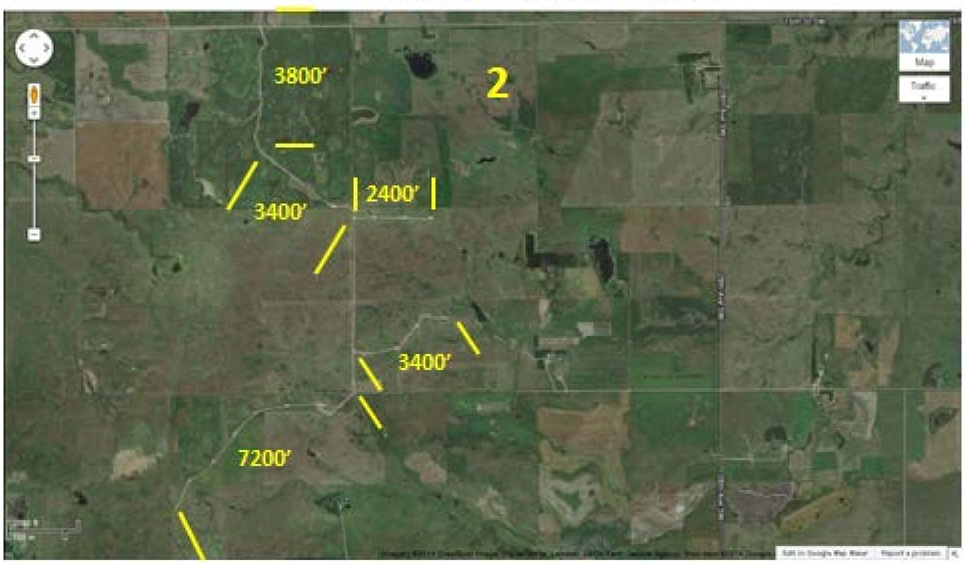
Oliver Wind Energy II, North Dakota Area 1



Area 1 Access Roads = (3900 + 4300 + 4000 + 2500 + 7700) * 40 = 1,056,000 ft^2 = 24.24 acres.

Figure 207. Oliver Wind Energy II Wind Farm Area 1.

Oliver Wind Energy II, North Dakota Area 2



Area 2 Access Roads = (3800 + 3400 + 2400 + 3400 + 7200) * 40 = 808,000 ft^2 = 18.55 acres.

Figure 208. Oliver Wind Energy II Wind Farm Area 2.

Table 41. Oliver Wind Energy II Wind Farm Summary.

Oliver Wind Energy II, North Dakota

Name	State	No. Of Turbines	Capacity MW	Gross Total Area (acres)	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	Hectares per MW	MJ per Hectare	Transmission	Commissioned	Electricity Purchaser	Owner / Operator
Oliver Wind Energy II	ND	32	48.6	20960	8482	175	174.53	20.63	Unknown	2007	Minnesota Powe	NextEra Energy

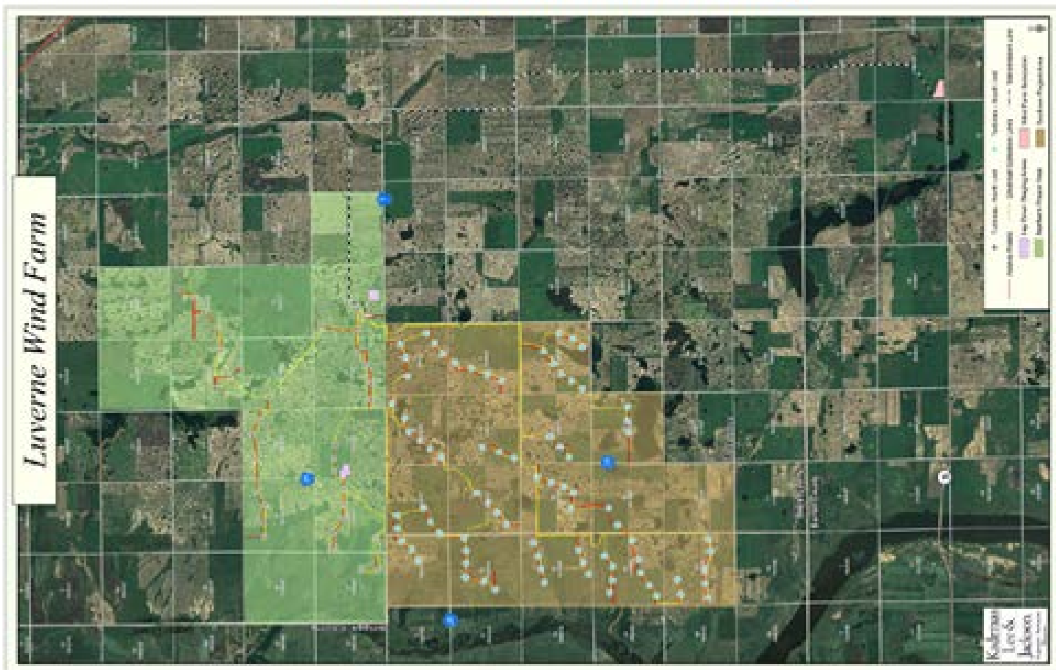
Information is based on gross area of the Wind Farm measured from Google maps.

Name	State	No. Of Turbines	Capacity MW	Actual Total Area (acres)	Actual Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	MJ per Hectare	Turbine Foundation Area (acre)	Access Roads (acre)	Substation Area (acre)	Turbine Height (ft)	CO2 Savings metric tonnes/yr	Type of Turbine	Turbine Namplate (MW)
Oliver Wind Energy II	ND	32	48.6	46	19	0.38	9401	3	43	0		Unknown	GE XLE	1.5

Using only the permanently disturbed land for the Wind Farm (access roads, substation, wind turbine foundation and structure, etc.), the MJ per Hectare increases from 20.63 to 9401 MJ per Hectare.

Appendix X Luverne North Wind Farm

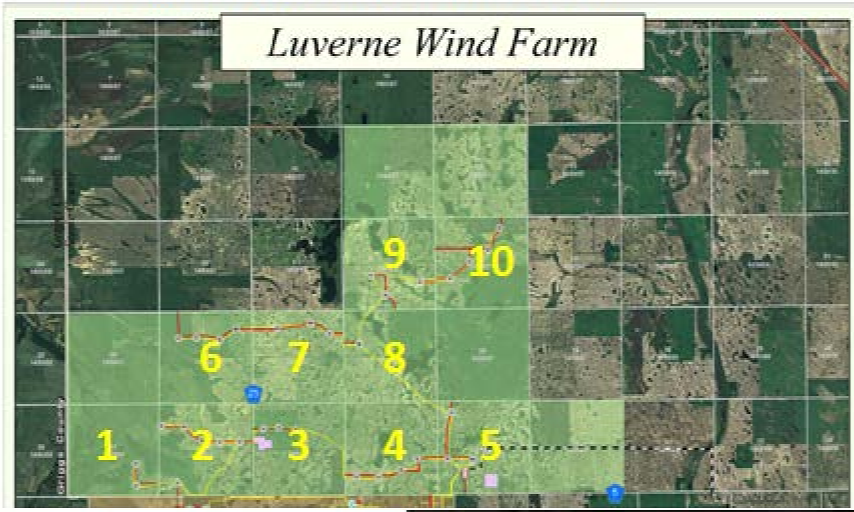
Luverne Wind Farm, North Dakota Overview

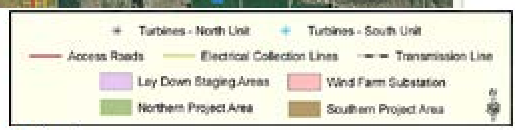


Reference: http://mpowernd.com/?page=Projects

Figure 209. Luverne North Wind Farm Overview.

Luverne North Field Wind Farm, North Dakota Overview





Each project area = 1 sq. mile = 640 acres.
North Field = 15 square miles =
9600 acres.

Reference: http://mpowernd.com/?page=Projects

Figure 210. Luverne North Wind Farm with Defined Measurement Areas

Luverne North Field Wind Farm, North Dakota Overview

Access Roads are approximately 40 feet wide.
Wind Turbine foundations are 80 feet in diameter = 5026 ft^2 = 0.12 acre.
33 Wind Turbines * 0.12 acres each = **3.96 acres for all foundations.**

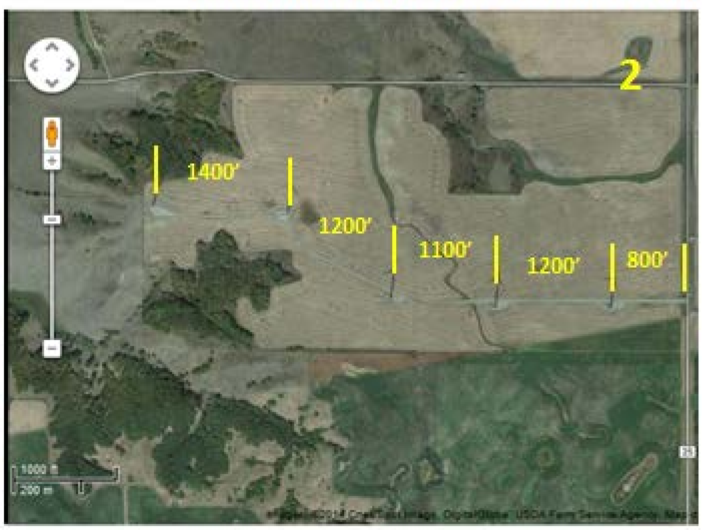
Figure 211. Luverne North Wind Farm Access Roads.

Luverne North Field Wind Farm, North Dakota Area 1

Area 1 Access Roads = (1200 + 1200 + 800) * 40 = 128,000 ft^2 = 2.94 acres.

Figure 212. Luverne North Wind Farm Access 1.

Luverne North Field Wind Farm, North Dakota Area 2



Area 2 Access Roads = (1400 + 1200 + 1100 + 1200 + 800) * 40 = 228,000 ft^2 = 5.23 acres.

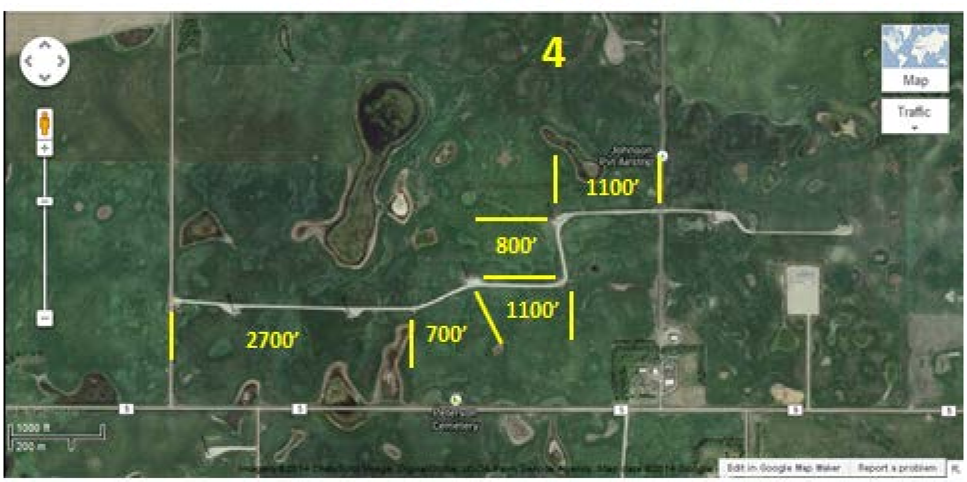
Figure 213. Luverne North Wind Farm Area 2.

Luverne North Field Wind Farm, North Dakota Area 3

Area 3 Access Roads = 2700 * 40 = 108,000 ft^2 = 2.48 acres.

Figure 214. Luverne North Wind Farm Area 3.

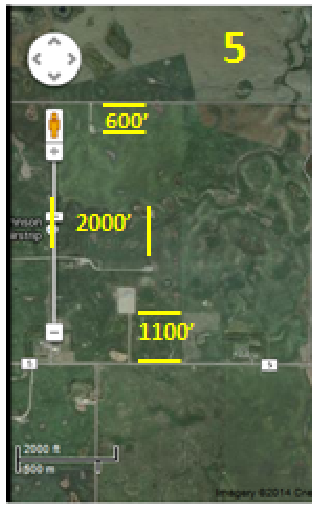
Luverne North Field Wind Farm, North Dakota Area 4



Area 4 Access Roads = (2700 + 700 + 1100 + 800 + 1100) * 40 = 256,000 ft^2 = 5.88 acres.

Figure 215. Luverne North Wind Farm Area 4.

Luverne North Field Wind Farm, North Dakota Area 5



Area 5 Access Roads = (600 + 2000 + 1100) * 40 = 148,000 ft^2 = 3.40 acres.

Figure 216. Luverne North Wind Farm Area 5.

Luverne North Field Wind Farm, North Dakota Area 5 Substation

Area 5 Substation = 460 * 640 = 294,400 ft^2 = 6.76 acres.

Figure 217. Luverne North Wind Farm Substation.

Luverne North Field Wind Farm, North Dakota Area 6

Area 6 Access Roads = (1100 + 500 + 1700 + 1100 + 850) * 40 = 210,000 ft^2 = 4.82 acres.

Figure 218. Luverne North Wind Farm Area 6.

Luverne North Field Wind Farm, North Dakota Area 7 & 8

Areas 7 & 8 Access Roads = (3100 + 500 + 1400 + 800 + 900) * 40 = 268,000 ft^2 = 6.15 acres.

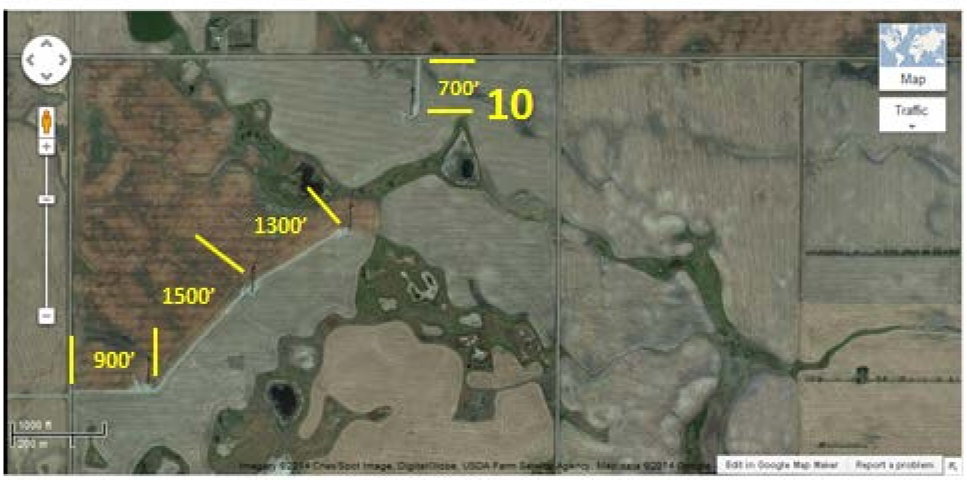
Figure 219. Luverne North Wind Farm Areas 7 and 8.

Luverne North Field Wind Farm, North Dakota Area 9

Area 9 Access Roads = (900 + 1200 + 600 + 400 + 900) * 40 = 160,000 ft² = 3.67 acres.

Figure 220. Luverne North Wind Farm Area 9.

Luverne North Field Wind Farm, North Dakota Area 10



Area 10 Access Roads = (900 + 1500 + 1300 + 700) * 40 = 176,000 ft² = 4.04 acres.

Figure 221. Luverne North Wind Farm Area 10.

Table 42. Luverne North Wind Farm Summary.

Luverne North Field Wind Farm, North Dakota

Name	State	No. Of Turbines	Capacity MW	Gross Total Area (acres)	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	Hectares per MW	MJ per Hectare	Transmission	Commissioned	Electricity Purchaser	Owner / Operator
Luverne North Field Wind Farm	ND	33	49.5	9600	3885	78	78.48	45.87	230 kV	2009	Minnkota Power Cooperative	Ottertail Power Co

Information is based on gross area of the Wind Farm measured from Google maps.

Name	State	No. Of Turbines	Capacity MW	Actual Total Area (acres)	Actual Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	MJ per Hectare	Turbine Foundation Area (acre)	Access Roads (acre)	Substation Area (acre)	Turbine Height (ft)	CO2 Savings [illegible]	Type of Turbine	Turbine Namplate (MW)
Luverne North Field Wind Farm	ND	33	49.5	49	20	0.40	8926	4	39	7	260	Unknown	GE XLE	1.5

Using only the permanently disturbed land for the Wind Farm (access roads, substation, wind turbine foundation and structure, etc.), the MJ per Hectare increases from 45.87to 8926 MJ per Hectare.

Appendix Y Cedar Hills Wind Farm

Cedar Hills Wind Farm, North Dakota
Near Rhame, ND (Point A)

Cedar Hills Wind Farm (encircled) located NW of Rhame, ND (point A) above.

Figure 222. Cedar Hills Wind Farm Overview.

Cedar Hills Wind Farm, North Dakota

Area 1 = 2800 * 3500 = 9,800,000 ft² = 224.98 acres. Area 2 = 2650 * 2900 = 7,685,000 ft² = 176.42 acres. Area 3 = 4200 * 2800 = 11,760,000 ft² = 269.97 acres. Area 4 = 1500 * 1300 = 1,950,000 ft² = 44.77 acres. **Total gross area is 716.14 acres.**

Figure 223. Cedar Hills Wind Farm with Defined Measurement Areas.

Cedar Hills Wind Farm, North Dakota

Access Road south of Highway 12 (16th Ave. N) are 130 feet wide.
Wind Turbine pad is 280 feet in diameter which is 61575 ft² or 1.41 acres each.
13 Turbines * 1.41 acres = **18.33 acres for turbine pads.**
Ref: https://maps.google.com/

Figure 224. Cedar Hills Wind Farm Access Roads.

Cedar Hills Wind Farm, North Dakota

Access Road: 1st set of 5 Wind Turbines = 3400 * 130 = 442,000 ft² or 10.15 acres
Mini-Access Road between Turbine Sets = 2500 * 12 = 30,000 ft² or 0.69 acres
Main Access Road between Turbine Sets = 2700 * 130 = 351,000 ft² or 8.06 acres
Access Road: 2nd set of 4 Wind Turbines = 2500 * 130 = 325,000 ft² or 7.46 acres
Switchyard area = 350 * 400 = 140,000 ft² or 3.21 acres. Access Road = 250*150 = 37,500 ft² or 0.86 acres

Figure 225. Cedar Hills Wind Farm Area 1.

Cedar Hills Wind Farm, North Dakota

Access Road: 3rd set of 4 Wind Turbines = 5000 * 130 = 650,000 ft² or 14.92 acres

Figure 226. Cedar Hills Wind Farm Area 2.

Table 43. Cedar Hills Wind Farm Summary.

Cedar Hills Wind Farm, North Dakota

Information is based on gross area of the Wind Farm measured from Google maps.

Name	State	No. Of Turbines	Capacity MW	Gross Total Area (acres)	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	MJ per Hectare	Commissioned	Electricity Purchaser	Owner / Operator
Cedar Hills Wind Farm	ND	13	19.5	716	290	14.86	242.27	2010	MDU Utilities	MDU Utilities

Information is based on actual permanently disturbed Wind Farm area measured from Google maps.

Name	State	No. Of Turbines	Capacity MW	Actual Total Area (acres)	Actual Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	MJ per Hectare	Turbine Foundation Area (acre)	Access Roads (acre)	Substation Area (acre)	CO2 Savings metric tonnes/yr	Type of Turbine	Turbine Namplate (MW)
Cedar Hills Wind Farm	ND	13	19.5	64	26	1.32	2724	18	42	3	Unknown	GE XLE	1.5

Using only the permanently disturbed land for the Wind Farm (access roads, substation, wind turbine foundation and structure, etc.), the MJ per Hectare increases from 242.27 to 2724 MJ per Hectare.

Appendix Z Velva Wind Farm

Velva Wind Farm, North Dakota

Velva Wind Farm – Overview located 2 miles North of Velva, ND off of Highway 41 .

Figure 227. Velva Wind Farm Overview

Velva Wind Farm, North Dakota

First Nine Wind Turbine Land Use.
Area of triangle is ½(b*h) = ½(200*1100) = 110,000 ft^2 = 2.53 acres. The large rectangle is 1500 * 1100 = 1,650,000 ft^2 = 37.88 acres. Trapezoid is ½*400(250+650)=180,000 ft^2 = 4.13 acres. Triangle is ½(250*10000) = 125,000 ft^2 = 2.87 acres. Area 1 total is 47.41 acres. Area 2 is 1400 * 1800 = 2,520,000 ft^{2}- 57.85 acres. **Total area is 105.26 acres.**

Figure 228. Velva Wind Farm Area 1.

Velva Wind Farm, North Dakota

Second Nine Wind Turbine Land Use.
The large area is 4000 *1000 = 4,000,000 ft^2 = 91.83 acres. The smaller area is 1700*1000 = 1,700,000 ft^2 = 39.03 acres. **Total area is 130.86 acres.**

Figure 229. Velva Wind Farm Area 2.

Table 44. Velva Wind Farm Summary.

Velva Wind Farm, North Dakota

Name	State	No. Of Turbines	Capacity MW	Gross Total Area (acres)	Gross Total Area (hectares)	Total Area Per Unit Capacity Hectares/MW	Hectares per MW	MJ per Hectare	Commissioned	Electricity Purchaser	Owner / Operator
Velva Wind Farm	ND	18	11.8	238	96	8.16	8.16	441.05	2005	XCEL Energy	Acciona

Information is based on gross area of the Wind Farm measured from Google maps.

Appendix AA Haubenschild Farms Anaerobic Digester Facility

Figure 230. Haubenschild Farms Location.

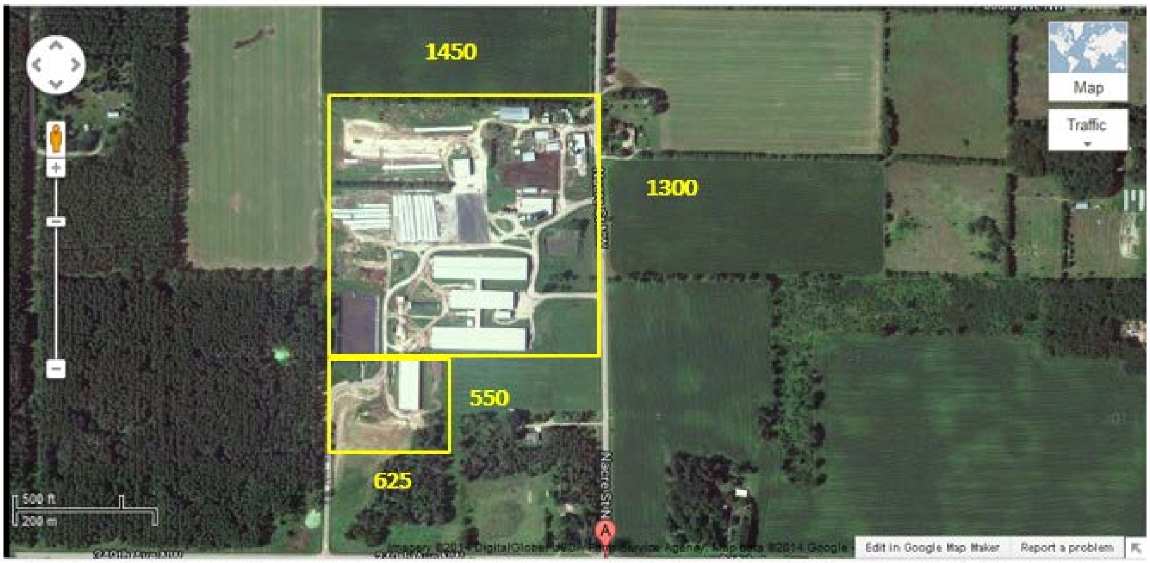
Haubenschild Farms

Location	Princeton, Minnesota
Project Type	Farm Scale
Animal Type	Dairy
Population Feeding Digester	900
Baseline System	Storage Tank or Pond or Pit
Digester Type	Horizontal Plug Flow
System Designer	RCM International, LLC
Biogas Generation	70,000 ft3/day
Biogas Use	Cogeneration; Electricity
Generating Capacity	155 kW
Receiving Utility	East Central Energy

Haubenschild Farms Inc
Haubenschild Farm Dairy, Inc,Haubenschild Farms
7201 349th Avenue NW
Princeton, MN 55371 - View Map
Phone: (763) 389-2867

Reference: http://www.epa.gov/agstar/projects/profiles/midwestdairyinstitute.html and http://www.manta.com/c/mm5cpvy/haubenschild-farms-inc

Figure 231. Haubenschild Farms Data.



Permanent Land Disturbances = (1450 * 1300) + (625 * 550) = 1,885,000 ft^2 + 343,750 ft^2 = 2,2,228,750 ft^2 = 51.17 acres (including barns).

Figure 232. Haubenschild Farms Permanent Land Disturbances.

Table 45. Haubenschild Farms Summary

Farm/Project Name	City	State	Digester Type	Year Operational	Animal Type	Population Feeding Digeste	Biogas End Use(s)	Installed Capacity (MW)
Haubenschild Farms	Princeton	MN	Horizontal Plug Flow	1999	Dairy	900	Cogeneration; Electricity	0.62

System Designer	Baseline System	Receiving Utility	Permantly Disturbed Land (incl. barns), h	MJ/Ha	Methane Emission Reductions (metric tons CH4/yr)	Methane Emission Reductions (metric tons CO2E/yr)
RCM International, LLC	Storage Tank or Pond or Pit	East Central Energy	20.71	107.774	62.82896254	1319.408213

Appendix AB District 45 Dairy Anaerobic Digester Facility

Reference: http://epa.gov/agstar/projects/index.html

Figure 233. District 45 Dairy Location.

District 45 Dairy

Location	Hancock, Minnesota
Project Type	Farm Scale
Animal Type	Dairy
Population Feeding Digester	5,520
Baseline System	Storage Lagoon
Digester Type	Mixed Plug Flow
System Designer	DVO, Inc. (formerly GHD, Inc.)
Biogas Use	Cogeneration
Generating Capacity	2,130 kW
Boiler Capacity	4,000,000 Btu/hr
Receiving Utility	Otter Tail Power

Midwest Dairy Institute is located 4 miles south of Midbank on Highway 15, then turn east onto 153rd Ave. for 2 miles.
Reference: http://www.epa.gov/agstar/projects/profiles/midwestdairyinstitute.html

Figure 234. District 45 Diary Data.

Permanent Land Disturbances = (1600 * 1500) = 2,400,000 ft^2 = 55.10 acres (including barns).

Figure 235. District 45 Dairy Permanent Land Disturbances.

Table 46. District 45 Dairy Summary

Farm/Project Name	City	State	Digester Type	Year Operational	Animal Type	Population Feeding Digeste	Biogas End Use(s)	Installed Capacity (MW)
District 45 Dairy	Hancock	MN	Mixed Plug Flow	2010	Dairy	5520	Cogeneration	2130

Baseline System	Receiving Utility	Permantly Disturbed Land (incl. barns), h	MJ/Ha	Methane Emission Reductions (metric tons CH4/yr)	Methane Emission Reductions (metric tons CO2E/yr)
Storage Lagoon	Otter Tail Power	22.3	343.8565	1134.680261	23828.28547

Appendix AC Northern Plains Dairy Anaerobic Digester Facility

Reference: http://epa.gov/agstar/projects/index.html

Figure 236. Northern Plains Dairy Location.

Northern Plains Dairy

Location	St. Peter, Minnesota
Project Type	Farm Scale
Animal Type	Dairy
Population Feeding Digester	3,000
Baseline System	Storage Tank or Pond or Pit
Digester Type	Horizontal Plug Flow
System Designer	RCM International, LLC
Biogas Use	Cogeneration
Generating Capacity	260 kW

Northern Plains Dairy
43475 County Road 15
Nicollet, MN 56074 - View Map
Phone: (507) 931-2091

Reference: http://www.epa.gov/agstar/projects/profiles/midwestdairyinstitute.html and http://www.manta.com/c/mr5lh9q/northern-plains-dairy

Figure 237. Northern Plains Diary Data.

Permanent Land Disturbances = (750 * 2850) = 2,137,500 ft^2 = 49.07 acres (including barns).

Figure 238. Northern Plains Dairy Permanent Land Disturbances.

Table 47. Northern Plains Dairy Summary

Farm/Project Name	Population Feeding Digeste	Biogas End Use(s)	Installed Capacity (MW)	System Designer	Baseline System
Northern Plains Dairy	3000	Cogeneration	0.26	RCM International, LLC	Storage Tank or Pond or Pit

Permantly Disturbed Land (incl. barns), h	MJ/Ha	Methane Emission Reductions (metric tons CH4/yr)	Methane Emission Reductions (metric tons CO2E/yr)
19.86	47.12991	209.4298751	4398.027378

Appendix AD Midwest Dairy Anaerobic Digester Facility

Reference: http://epa.gov/agstar/projects/index.html

Figure 239. Midewest Dairy Location.

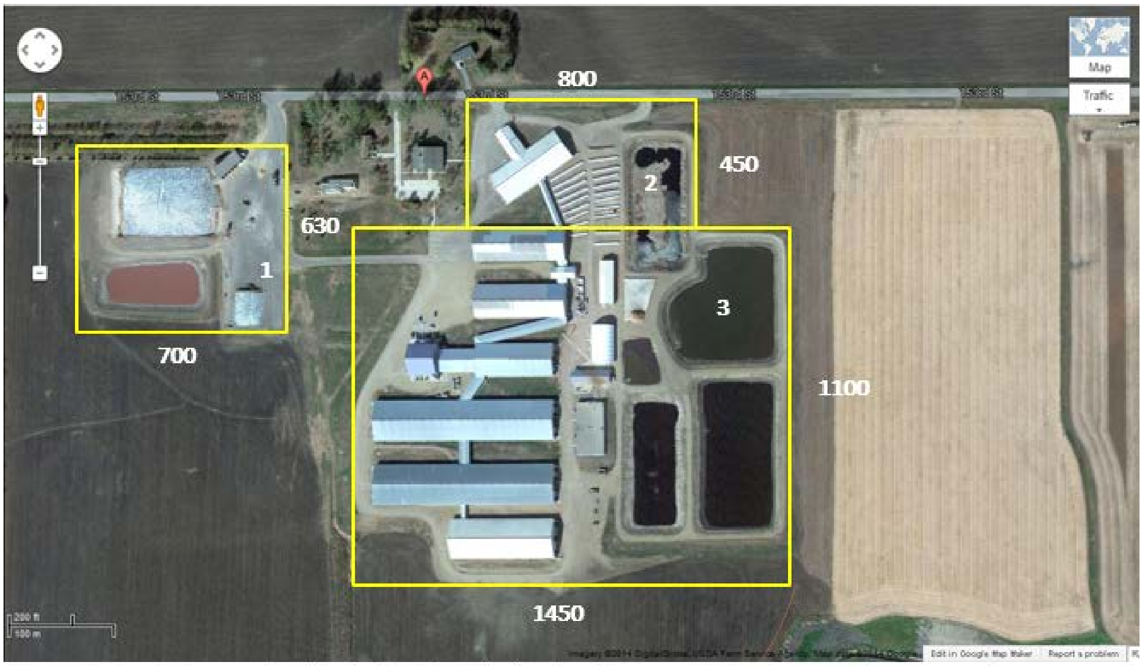
Midwest Dairy Institute

Location	Milbank, South Dakota
Project Type	Farm Scale
Animal Type	Dairy
Population Feeding Digester	2,400
Baseline System	Storage Tank or Pond or Pit
Digester Type	Plug Flow
Biogas Use	Boiler/Furnace Fuel; Electricity
Generating Capacity	375 kW
Receiving Utility	Whetstone Valley Electric Cooperative

⇧Top of page

Midwest Dairy Institute is located 4 miles south of Midbank on Highway 15, then turn east onto 153rd Ave. for 2 miles.
Reference: http://www.epa.gov/agstar/projects/profiles/midwestdairyinstitute.html

Figure 240. Midwest Dairy Data.



Permanent Land Disturbances = (700 * 630) + (1450 * 1100) + (800 * 450) = 441,000 = 1,595,000 + 360,000 ft^2 = 2,396,000 ft^2 = 55.00 acres (including barns).

Figure 241. Midwest Dairy Permanent Land Disturbances.

Table 48. Midwest Dairy Summary

Farm/Project Name	City	State	Digester Type	Year Operational	Animal Type	Population Feeding Digeste	Biogas End Use(s)	Installed Capacity (MW)
Midwest Dairy Institute	Milbank	SD	Plug Flow	2006	Dairy	2400	Boiler/Furnace Fuel; Electricity	1.5

Baseline System	Receiving Utility	Permantly Disturbed Land (incl. barns), h	MJ/Ha	Permantly Disturbed Land (w/o. barns), I	MJ/Ha (w/o barns	Methane Emission Reductions (metric tons CH4/yr)	Methane Emission Reductions (metric tons CO2E/yr)
Storage Tank or Pond or Pit	Whetstone Valley Electric Cooperative	22.26	242.61	13.13	411.21	182.5114646	3832.740756

VITA

Carlo Stephen Ciliberti, Jr. was born in New London, Connecticut, grew up in Bellmawr, NJ and currently resides in Lumberton, NJ. Mr. Ciliberti began his engineering endeavor as an undergraduate at Temple University, where he studied biomedical engineering. His career began at the Naval Ship Systems Engineering Station (NAVSSES) as an Electrical Engineer in instrumentation conducting IR surveys of aircraft carrier electrical systems, mil-spec testing and fleet support. Following NAVSSES, Mr. Ciliberti worked for Fluor Daniel as a Control Systems Engineer in Pharmaceutical /Biotechnology and advanced to Project Engineer while earning a MSEE from Widener University and a PE License.   He was then the Instrumentation and Control Systems Department Manager for CDI Engineering before joining Lockheed Martin in 2004. While at Lockheed Martin, he earned a second Master's degree in Engineering Management from Drexel University and continued at Drexel pursuing his PhD in Engineering Management in the Civil Engineering Department. He is currently a Project Engineer in Lockheed Martin's Energy division.

Mr. Ciliberti's publications include:

- "The Impact of Open Architecture on US Navy's Aegis Requirements Engineering", Maritime Systems and Technology for Defence, Security and Safety
- "Integrated System to Supply Power and Fuel to Rural Districts Using Renewable Resources", American Society of Engineering Management 2014 Proceedings
- "Business Model to Supply Rural Electric Cooperatives with an Integrated Renewable Energy", Proceedings of the American Society for Engineering Management 2015 International Annual Conference
- "A Life Cycle Perspective on Land Use and Project Economics of Electricity from Wind and Anaerobic Digestion" Energy Policy